STUDIES OF THE EFFECT OF FOLIAR NUTRITION ON THE GROWTH AND YIELD OF BARLEY AND MUSTARD

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CERTIFICATE

This is to certify that the thesis entitled "Studies of the effect of foliar nutrition on the growth and yield of barley and mustard" submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Botany, is a faithful record of the bonafide research work carried out at the Aligarh Muslim University, Aligarh by Miss Alia Naqvi under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

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C O N T E N T S

Chapter 1

INTRODUCTION

1. INTRODUCTION

The "Green Revolution" which has ushered in an era of great promise for this country on the food front has also brought with it certain problems both for the farmer and the Government. The most important single factor responsible for this miracle is the release of a number of new varieties of food plants having a much higher yield potential than the traditional varieties. Another significant contributing factor has been the considerable increase in the acreage under cultivation. Paradoxically, these very factors pose the worst problems. The new high yielding varieties require much larger fertiliser doses and other inputs for optimum performance as compared with the old varieties. The additional land brought under the plough also needs more attention and expenditure. Much of it lies in areas where facilities for irrigation are wanting. Inspite of the large-scale measures taken by the Government to solve these problems, the situation leaves much to be desired. Particularly, the fertiliser position is far from satisfactory. The sharp rise in the cost of inputs, coupled with the consumer oriented fixation of the market price of the important food grains by the Government would dampen the enthusiasm of the farmers. The results of this could be disastrous unless remedial measures are found and quickly brought to the notice of the affected peasantry.

With this in view, Afridi and associates, at Aligarh, have embarked upon a programme to study the feasibility of saving costly fertiliser, particularly phosphate, with a good measure of success in barley (Afridi and Samiullah, 1973).

It is well known that much of the phosphatic fertiliser added to the soil at the time of sowing soon becomes unavailable to the plants (Russell,1950, p. 58). Inspite of its relative mobility in the plant, the fixation of phosphorus in the soil might endanger the well being of crops, particularly of the high yielding varieties, by inducing a hidden hunger, specially at the time of formation of fruits and seeds which are known to accumulate this nutrient. It is to offset this situation that top dressing with fertilisers at later stages of crop growth is generally recommended. The addition of solid fertiliser to standing crops, however, has its own disadvantages. In recent years, the alternative method of foliar nutrition has established itself as more effective, economical and easy to manage. Application of fertiliser directly to the leaves and other aerial organs, from which it is readily absorbed and translocated, ensures its quick metabolism. The quantity of the fertiliser sprayed is much less than that added as top dressing and loss due to further fixation in the soil is cut down. The operational costs are negligible as foliar feeding could be adjusted as a part of normal pest control measures which would be undertaken anyhow if optimal yields were to be ensured. Lastly, this method could be used to great advantage in dry land farming where large doses of solid fertiliser could be detrimental to the crops due to harmful osmotic effects on roots.

It may, however, be admitted that, inspite of its great promise, research on foliar nutrition is still in its infancy, particularly in India. Although some work has been done on the application of nitrogen (mostly in the form of urea) as leaf spray (Wittwer and Teubner, 1959, Anonymous, 1971), that on phosphorus is meagre (Samiullah, 1971). It may be added that foliar application of sulphur seems to have attracted no attention at all.

With the rapid increase in population, India has experienced not only a chronic shortage of food grains but also of edible oils during the past few decades. Concerted efforts have no doubt increased the gross national yield of cereals as a result of various measures taken including the diversion of more land for their cultivation but this has been achieved to some extent at the expense of oil seeds production. The problem of shortage of oil seeds has received nominal attention of farm scientists and has remained confined to the breeding of only a few high yielding varieties of mustard and the introduction of some non-traditional oil yielding plants such as sunflower. However, it may be added that although our farmer understands the advantage of growing the improved varieties of mustard and is willing to cultivate them, he is wary of the other oil bearing plants and it may take time to change his attitude. Moreover, it is surprising to note, that, inspite of its significant role in the metabolism of crucifers and other oil producing plants, no attention has been paid to the sulphur requirements of these plants.

In view of these facts, it was considered desirable to reinvestigate, in greater detail, some aspects of foliar application of phosphorus on NP13 barley. The effect of soil- and leaf-applied phosphorus and sulphur on Laha-101, an improved variety of mustard, was also considered worthy of investigation. These studies were based on varied statistical designs to obtain maximum information.

The following field experiments were conducted between 1969 and 1974 to study:

1. The effect of five doses of sprayed phosphorus i.e. 0, 1.365, 2.73, 5.46 and 10.92 kg P_2O_5/ha (the last two doses being higher than those applied by Samiullah, 1971 and Afridi and Samiullah, 1973) and of two doses of soil-applied phosphorus i.e. 0 and 30 kg P_2O_5/ha on growth characters and NPK content of NP13 barley at 70 and 90 days after sowing and on yield characters at harvest, according to a split plot design.

2. The effect of four doses of leaf-applied phosphorus (0-5.46 kg P_2O_5 /ha) with and without "Dimecron-100", a commercial insecticide, sprayed once at 70 days or twice at 70 and 90 days on the growth and NPK content of NP 13 barley at these two stages of growth and on yield characters at harvest, according to a randomised block design.

3. The effect of phosphorus and "Dimecron-100", on the growth and NPK content of Laha-101 at flowering and fruiting stages and on yield characters and seed quality at harvest, keeping the doses, timing of spray and design of experiment the same as in Experiment 2 above.

4. The effect of one dose each of leaf-applied phosphorus and sulphur (2.0 kg P_2O_5 / ha and 1.0 kg S / ha; respectively) singly or in combination, and of three doses of soil-applied phosphorus (0, 20 and 40 kg P_2O_5 / ha) on Laha-101 at flowering and fruiting stages on growth characters and NPK content at these two stages and on yield characters and seed quality at harvest, according to a factorial randomised design.

The statistically analysed data of these experiments and the conclusions drawn from them, discussed in the light of the publications of other workers, are presented in this thesis.

Chapter 2

REVIEW OF LITERATURE

C O N T E N T S

2. REVIEW OF LITERATURE

2.0 Introduction:

The primitive agricultural societies had learnt, presumably by trial and error, that addition of animal excreta and plant debris to the fields increased crop yields. Credit is, however, due to de Saussure (1804) for his pioneer efforts in establishing that, to a large extent, plants depended on the mineral elements present in the soil for their growth and development. Subsequently, these conclusions were endorsed by eminent farm scientists like Boussingault (1834) and Liebig (1840). In addition, Lawes and Gilbert, Sachs, Ville and others maintained, during the last century that manuring was the only way of keeping up soil fertility (Russell, 1950).

By about 1865, the list of the macronutrient elements essential for plants was completed but it took about another century to establish the essentiality of the few micronutrient elements, chlorine being the last in the list added in 1954 (Hewitt, 1963).

With the establishment of the importance of mineral elements, various methods for determining their requirements for plants were devised. The analysis of the soil was earlier regarded as a workable technique to determine its nutrient status, on which further studies of the mineral requirements of plants could be based. However, when reliability of soil analysis became questionable on account of the drawbacks now well known to students of agriculture, other methods were sought. A fascinating alternative was the analysis of the plant itself. Despite several difficulties, a steady progress was maintained, during the present century, in the development and application of this technique as a suitable tool for investigating the problems of plant nutrition. It was introduced by Hall (1905) for determining the nutrient content of plants as well as of the soil harbouring them. Hoffer (1926) was the first to devise rapid tissue tests for nitrate and potassium under field conditions using fresh plant material.

Other group of workers developed more accurate laboratory procedures of analysis by using dried plant material. Prominent among them were Lagatu and Maume (1934), Thomas (1937), Chapman (1941), Nightingale (1942) and Ulrich (1942). The concept of 'foliar diagnosis' was introduced by Lagatu and Maume (1934) and Thomas (1937). Refering to the classical investigation of Pierre (1869) who pointed to the sensitivity of leaves in exhibiting changes in their composition under different environmental conditions, Thomas and Mack (1939) stressed the importance of a nutritional balance in leaves for the healthy growth of plants.

Lundegårdh (1947) arrived at a similar conclusion, as a result of prolonged experiments with sugarbeet. According to him, leaves have a deciding influence on the quantities of nutrients transported to the growing shoots and fruits because of their central functions such as photosynthesis and protein formation. He found a positive relationship between the nutrient elements in leaves and vegetative growth. In India, the technique of foliar diagnosis has been successfully applied to the study of the fertiliser requirements of field crops. Among these, barley has received considerable attention (Chandersekhara and Sundara Rao, 1956; Das, 1955,59; Safaya, 1971 and Samiullah, 1971). At Aligarh, interest has been focussed by Afridi and associates on the phosphate requirement of this crop. In fact, as expressed earlier (p. 4), the present investigation was partly planned to extend the study of Samiullah (1971) with particular emphasis on the effect of foliar applied phosphorus. The remaining part of this review is, therefore, confined mainly to the literature on this aspect. However, a few important references on soil application are also included for the sake of comparisons.

2.1. <u>Phosphorus as a plant nutrient</u>:

Phosphorus has been recognised for more than a century as an essential element for plant growth and vigour. The first to demonstrate the presence of phosphorus in the ash of plant was de Saussure (1804). The essentiality of phosphorus for plants was stressed by subsequent workers including Boussingault (1838), Liebig (1840), Lawes and Gilbert (1847) and others. Since then an ever-increasing number of workers has tested the efficacy of phosphorus for the growth and yield of crop plants. However, being largely irrelevant in the context of the present work, a review of the enormous literature on the requirement of fertiliser phosphorus by crop plants would be futile. Therefore, an attempt will be made to confine it to the publications concerning barley and mustard. It may also be mentioned that the earlier work on fertiliser phosphorus has been adequately covered in a number of books and reviews, including Russell (1950), Das (1955), Black (1968), Safaya (1971) and Samiullah (1971). Moreover, with the introduction of the new high yielding varieties, much of the older data may not be relevant. It is, therefore, proposed to consider critically only the more important publications from India during the last two decades or so.

The first detailed study during the period under consideration was that of Das (1959) on C-251 variety of barley.

He studied the effect of different doses of superphosphate at the rate of 20, 40, 60, 80 and 100 lb P_2O_5 / acre on the growth, yield and composition of barley. He observed that: (1) low doses (20 or 40 lb P_2O_5 /acre) increased height, tiller number and leaf area whereas higher doses showed a gradual fall, except in the case of height which was depressed by 60 lb P_2O_5 / acre and again showed a rise at 80 or 100 lb P_2O_5 / acre; (2) leaf and stem dry weight also showed an increase due to application of low doses of superphosphate and high doses brought initial depression which later on disappeared; (3) many growth characters, viz., height of the plant, tiller number, leaf number, leaf dry weight and stem dry weight showed positive correlations amongst themselves as well as with the nutrient composition of the leaf; (4) the effect of phosphorus on different ear characters showed two trends: (i) a significant increase due to 20 lb P_2O_5 / acre, followed by a depression at the next higher dose, and (ii) a significant increase due to 60 lb P_2O_5 / acre followed by a gradual decrease at the two higher doses; (5) grain yield was increased with increase in phosphate doses. 80 lb P_2O_5 / acre was found to be the optimum whereas 100 lb P_2O_5 / acre showed a slightly lower grain yield. Highest straw/grain ratio was reported in the control. Among the treatments, 60 lb P_2O_5 / acre showed the highest ratio indicating comparatively larger straw yield. It is, however, an intriguing observation and surprisingly no explanation has been given; (6) a correlation between leaf phosphorus and straw yield was observed; (7) finally, the effect of fertiliser phosphorus could be distinguished into two categories, characterised by the age of the plants. The plants exhibited to some extent a similar trend in many of the characters studied upto the heading stage but after this the trend followed a slightly different course.

Sen (1960) also came to a generally similar conclusion with two barley varieties, namely Kanpur 251 and NP13. From his field experiments, extended over a period of three years, he concluded that: (1) the responses to nitrogenous and phosphatic fertilisers on annual yields, as well as on cumulative yield for the total period of three years, were linear; (2) the highest doses 40 lb N and 60 lb P_2O_5 / acre gave significantly higher yields than the no-fertiliser control; (3) the lower dose of nitrogen (20 lb N / acre) was optimum for maintaining the malting quality of the grain; (4) the highest dose of phosphorus (60 lb P_2O_5 / acre) reduced the nitrogen content of the grain to a low enough level to render the grain desirable for malting, irrespective of the dose of nitrogen added and (5) finally, of the two varieties, NP13 gave significantly higher yields than Kanpur 251.

At Aligarh, Safaya (1971) studied the effect of phosphorus alone or in combination with nitrogen and potassium in sand culture and field on three varieties of barley, namely NP 13, NP 21 and NP 104. He found that all the three varieties of barley responded more to combined doses as compared with nitrogen, phosphorus and potassium singly, 80:60:60 lb N, P_2O_5 and K_2O / acre proving the optimum. Nitrogen, giving best results, was found to increase straw yield by accelarating dry matter accumulation at vegetative stages of growth, whereas, phosphorus or potassium showed a highly beneficial effect on grain setting. From sand culture studies, he deduced that phosphorus application beyond 8 me PO_4^{---}/1 caused a depression in the growth of barley. Variety NP 21 was reported to have a higher requirement for phosphorus which could also be due to its lesser ability for phosphorus absorption. It is not clear, however, why the experiment was not carried out to its logical conclusion, so that the effect of various levels of phosphorus could be assessed on ear characteristics as well as total yields per plant.

The effect of fertilisers on the uptake of nitrogen and phosphorus by NP 21 barley under different moisture regimes was studied by Sharma and Singh (1973). They reported that application of phosphorus at the rate of 17.5 kg P / ha increased the nitrogen and phosphorus uptake over the control by 7.8 and 5.1 per cent respectively.

Finally, Afridi and Samiullah (1973) reported that, in the presence of adequate nitrogen and potassium, application of 30 kg P_2O_5 / ha increased the yield of NP13 variety of barley by about 12 per cent whereas an additional top dressing with 30 kg P_2O_5 / ha 70 days after sowing increased it by another 2 per cent over the 0 kg P_2O_5 / ha control. It is thus clear that the initial application of 30 kg P_2O_5 / ha, which was otherwise sufficient to sustain vegetative growth, was not adequate for optimum yields. It may be mentioned here to strengthen this conclusion that Samiullah (1971) had earlier recorded a significant beneficial effect of phosphate dressing on several growth components, including plant height, leaf and tiller number as well as fresh and dry weight at the late tillering stage.

The beneficial effect of phosphate dressing on the new Indian barley varieties included above seems to be corroborated by work abroad. Increase in grain yield through better fertiliser uptake and consequent improvement in vegetative and reproductive growth has been reported, among others, by van der Paauw (1952), Atkins et al. (1955), Fujiwara and Ohira (1960), Dalas et al. (1961), Reichman and Grunes (1966), Webber et al. (1968), Salmin (1969), Avramchuk (1970) Budoi et al. (1970), Radney (1970) and Simeonov and Velchev (1970).

A discordant note has, however, been sounded by Singh and Dass (1960) who found that the higher dose of phosphorus

(50 lb P_2O_5 / acre) had a depressing influence on the yield of barley. It may be pointed out that this study was based more on the economics of inputs and yields rather than on purely academic considerations. For example, in the same study, while recommending 33 lb N/acre, these authors admit that "the optimum dose of nitrogen for wheat crop, however, lies beyond 50 lb N/acre."

As compared with barley, studies on the fertiliser response of mustard and rape are scant. Sen and Sarkar (1958) studied the effect of various levels of phosphorus (ranging between acute deficiency and excess) on the growth, yield and oil content of _Brassica juncea_ in sand culture. They claimed to maintain the ionic balance and pH of the culture solution applied by adding appropriate amounts of $NaSO_4$, 10 H_2O to the three P-deficient solutions.

They concluded that both the higher and lower doses of phosphorus significantly increased total height of the main shoot, branching, leaf production and total dry weight of plants. However, the effect of the treatments on flowering, fruiting, seed yield and oil content was non-significant. The explanation given for the unexpected enhancing effect on growth characteristics of low doses of phosphorus is, however, not very convincing. They claimed that the sulphur added as $NaSO_4$, 10 H_2O to the deficient cultures compensated, to some extent, for the lack of phosphorus for which no explanation is given.

It is, however, surprising to note that, out of the established micronutrient elements, only iron and manganese were included in the nutrient solutions. The degree of purity of the sand and macronutrients used and the material of which the pots were made, is also not indicated. It may, therefore, be presumed that if purified sand, chemicals and water were used and the pots were of such material that they would not chemically contaminate the cultures, the latter would have suffered more or less from deficiencies at least of copper, and zinc, if not of boron and molybdenum also. On the other hand, in crude cultures that could be expected to supply the necessary micronutrients as contaminants, the data obtained and the conclusions drawn therefrom could at best be called as mere speculations. It is considered desirable that, in view of the importance of the problem, the study may be repeated under more rigorous checks.

Sharma (1968) studied the effect of three levels each of nitrogen, phosphorus and potassium on the yield of _Brassica juncea_. He noted significant increase in seed yield with increasing doses of nitrogen (0, 22.5 and 45.0 kg N/ha) and of phosphorus (0, 11.25 and 22.5 kg P_2O_5 / ha), but the effect of three doses of potassium (0, 11.25 and 22.5 kg K_2O/ha) was non-significant. He also worked out the economics of the various manurial treatments. He concluded that, as compared with the respective controls, 60.9 per cent net profit was obtained with the highest dose of nitrogen, 11.4 per cent with the highest dose of phosphorus and 11.0 and 15.8 per cent (albeit non-significantly) with the two doses of potassium, respectively, and recommended the application of 45.0 N, 22.5 P_2O_5 and 22.5 K_2O / ha for optimum yields of this crop.

However, it may be pointed out that this suggestion is based on mere speculation. The data reported by the author are based on a simple randomised block design and care should have been taken in recommending the optimum N P K dose for the crop. None-the-less, a repetition of the trial using a factorial randomised design, would surely be expected to lead to a more acceptable balanced manurial formulation for optimum yield of Brassica.

Honkhede et al. (1970) studied the effect of various factors (including fertilisers) on yield and quality of Indian rape (Brassica campestris). They found that application of phosphorus at the rate of 20 kg P_2O_5 / ha, along with 40 kg N/ha, increased the number of branches, number of capsules per plant and seed yield, whereas at higher fertiliser levels this trend was reversed. The plant height continued to increase with higher levels of fertiliser, but the oil content of the seed was reduced.

Mehrotra et al. (1972) grew Brassica juncea in 28 cm x 23 cm pots filled with loam soil. The plants were given a basal dose equivalent to 22 kg N, 11 kg P_2O_5 and 22 kg K_2O / ha The eight treatments consisted of four levels (0, 22, 44 and 66 kg) of N and two of P_2O_5 (0 and 22 kg) per hectare. The observations recorded at five stages of growth (seedling, branching, flowering, ripening and harvesting) revealed highest uptake of N P K from the soil, concentration of leaf nitrogen and phosphorus, total seed yeild and percentage of protein and oil in the seed by the application of 66 kg N plus 22 kg P_2O_5 / ha. Application of nitrogen (with or without phosphorus) at all levels depressed oil content but increased protein content of seed. Hence, a negative correlation was obtained between oil and protein contents. However, it may be pointed out that most of the results were non-significant.

Dhindsa et al. (1973) studied the effect of three combinations (0, 0; 50, 25 and 100, 25 kg N and P_2O_5 /ha) applied at the time of sowing which was done at five different dates and with two different row spacings in Brassica campestris. They concluded that significantly higher seed, oil and protein yields were obtained by the $N_{50}+P_{25}$ treatment;

the best time of sowing was the middle of September and the best spacing between rows, 30 cm. However, the data were significant only for the total seed yields. In fact, the oil percentage of seeds was found to decrease (albeit non-significantly) with increasing doses of nitrogen. The effect of added nitrogen on seed production was, however, so marked (about 10% and 8% over the control) for $N_{50} + P_{25}$ and $N_{100} + P_{25}$ respectively that the total yields of oil were found to be markedly increased over the yield of the control.

It may be relevant to add here that similar results have been published recently by Simanskii (1961), Dembiński et al. (1969) and Horodyski and Piecska (1970) in other countries.

2.2 Foliar fertilisation:

From the foregoing summary of recent publications on the fertiliser requirements of Indian varieties of barley and mustard, it is clear that the new high yielding strains require large doses of fertilisers for optimum performance. In this respect it is equally important to note that not all of the fertiliser applied to the soil is used by crops. A considerable proportion is rendered unavailable to the plants due to a number of factors, including fixation, leaching, decomposition by soil micro-organisms, etc. (Russell, 1950).

To avoid this wastage, a new line of approach has been adopted by agricultural workers. This consists of split application of fertilisers, partly to the soil at the time of sowing and partly as a dilute spray to the aerial parts of the plants at appropriate periods of growth. This technique of foliar nutrition has proved to be a feasible agricultural practice for many plants.

The idea of the supply of minerals to plants through their leaves is not new. Bould (1963) reported that Forsyth in 1803 was the first to use this technique. Wittwer and Teubner (1959) gave credit to Gris (1844) for publishing one of the earliest reports on foliar absorption of mineral nutrients. In the last century, Mayer (1874) and Böhm (1877), were among the notable workers in this field. However, the technique was mainly applied to correct micronutrient disorders with varying degrees of success and until the middle of the present century, wide spread use of macronutrients by foliar application was considered with scepticism but interest in the technique increased considerably thereafter.

However, a perusal of the publications during the last quarter century reveals that much more attention has been paid to nitrogen spray than to the application of other macronutrients including phosphorus and sulphur. In fact, hardly a dozen references have come to the notice of the present reviewer regarding the spray of these two latter nutrients on barley and mustard. It is, therefore, proposed that, for the sake of comparison with these two plants, a critical appraisal of the important publications on other cereals and oil-producing plants may also be included in the following pages.

The first use of phosphorus spray seems to have been mentioned in a preliminary report by Lewis (1936) who studied the absorption of phosphorus by lettuce leaves from a combined spray of nitrogen, phosphorus and potassium.

Later the availability of the radioactive isotope, P^{32}, facilitated basic as well as applied research in the field.

Biddulph (1941) seems to be among the earliest workers who used P^{32} in foliar nutrition studies. He reported a diurnal trend in the movement of P^{32} from the leaves of bean and established his theory of "circulation" of phosphorus in the plant. He also reported that the most rapid movement of P^{32} occurred from the leaves during the day hours mostly through the phloem. Later Biddulph (1951), Silberstein and Wittwer (1951), Eggert et al. (1952) and Swanson and Whitney (1953) studied the effect of sprays of variety of compounds containing P^{32} on the growth of vegetables, cereals and fruit trees. They noted rapid absorption of P^{32} sprayed on the leaves and its subsequent translocation from the leaves to all parts of the plants including roots, young fruits and meristems.

It may be pointed out that these studies were primarily aimed at the uptake and translocation of phosphorus, and no attempt was made to investigate the effect on yield. Silberstein and Wittwer (1951) were probably the first to study the effect of foliar application of this nutrient on the yield of tomato. They concluded that although leaf spray improved the performance of controls grown without basal phosphorus, it did not match the total yields obtained with full soil application. The only advantage of foliar phosphorus was found to be an enhancement of early yields of tomato.

Boynton (1954) reviewed in detail some aspects of foliar nutrition. He considered: (a) the effect of specific nutrients, including phosphorus, on the growth and yield of plants, (b) the effect of various factors on the absorption of these nutrients and (c) the practical applicability of the technique to agriculture and horticulture and the conditions that would determine its desirability.

It is obvious that research on foliar fertilization was in its infancy at the time this review appeared, particularly with regard to the application of macronutrients. Out of the 82 references cited, less than half a dozen were related to phosphorus. Amazingly, Boynton failed to find any reference regarding a positive nutritional response of plants to spray of sulphur. However, on the basis of consideration of publications on the effect of SO_2 fumes and sulphur fungicides, he seemed convinced that under conditions of sulphur deficiency, sprays of soluble sulphates could be expected to exhibit nutritional value and cause growth responses.

Concluding the review, Boynton (1954, p. 51) maintained that "it seems unlikely that foliar application will ever supplant soil application as a general practice. It also seems unlikely that proprietary mixtures of nutrients for foliar application serve a purpose that is generally useful. On the other hand, it is clear that foliar nutrition is a satisfactory means of dealing with a number of special problems that were not solved by other means. Undoubtedly as time goes on more special uses will be made of this method of fertilizing plants." This prophecy stood the test of time.

The review under consideration served a very important purpose. It focussed the attention of an ever increasing number of research workers on this unusual technique of fertilizer application as is evidenced by a spurt of publications soon after its appearance.

Kaindl (1954) reported that in cereals, spraying in the evening was better because the drying process was slower and dew formation the next morning remobilised the dried up nutrients. Moreover, conditions of high humidity were noted to promote leaf intake. He, therefore, recommended spraying with water alone after nutrient application to the leaves of fruit trees. In dorsiventral leaves, treatment of the lower surface was found to give better results. A combination of foliar and soil fertilisation gave higher yields as compared with either treatment alone. He also maintained that during vegetative growth, foliar sprays of phosphorus could be most effectively utilised by cereals at two stages of growth. Firstly, when they were a fortnight old after sowing and the growth cycle had not yet started and secondly when they were a month old when they were expected to possess maximum vitality.

Thorne (1954) concluded from one of her experiments that spraying with complete nutrient solution caused increases in nitrogen, phosphorus and potassium contents and dry weight of barley. Higher nutrient contents and dry weights of grains, straw and chaff, but not of roots contributed to this effect and the increased grain weight was entirely due to the extra tillers of the plants sprayed with nutrient solution because there was no effect of treatment on 1,000 grain weight or number of grains per ear.

In the end, she reported that plants sprayed with nutrient solution were darker green and ripened later than those sprayed with water. However, it may be pointed out that no explanation has been given for these observations which are not only interesting but have considerable importance. Late maturing in cereals is claimed by a number of workers to depend on the hydrature of the plants through its effect on their carbohydrate content (Curtis and Clark, 1950, p. 248). In the opinion of the present reviewer, the high nitrogen content of sprayed plants reported by Thorne, might have resulted in the preferential consumption of larger quantities of carbohydrates for the formation of protoplasm as shown by their higher dry weight associated with the darker green colour. The consequent depletion in their carbohydrate content might thus have been responsible for delayed filling and ripening of the grains in the treated plants.

The review by Wittwer and Teubner (1959) is a landmark in the history of foliar nutrition in more than one way. Appearing within five years of the earlier publication on this topic in the same journal (Boynton, 1954), it cites a large number of new publications of a varied nature, indicating the considerably increased interest of researchers in the problems of the mechanisms of uptake and translocation, metabolism and economic returns with regard to the applied nutrients. It is noteworthy that many of the citations were related to the macronutrients. This review on foliar nutrition is useful as it not only cited but also gave a critical assessment of most of the relevant information. Moreover, it included broad hints about future lines of research, particularly from the point of view of the agrotechnical efficiency of the method.

Some of the relevant generalisations and critical remarks on phosphorus and sulphur appearing in this review are summarised below:

The absorption of phosphorus and sulphur from leaves was rapid but whereas a low pH of the spray solution was reported to help phosphorus uptake that of sulphur seemed to be unaffected by pH. Generally, young leaves were noted to be more efficient for absorption than old leaves. Plants starved of phosphorus showed better absorption. There seemed little doubt that they were readily converted to complex organic fractions in the leaf and once absorbed both nutrients were translocated to other organs. However, it is noteworthy that the references to the effect of leaf-applied phosphorus and sulphur on yields of agronomic crops in general were few. None-the-less, pointed reference had been made regarding the potentiality, at least of the former, in colder climates where low soil temperatures in spring could greatly impede fertiliser uptake and consequently result in slower growth, whereas leaf spray, helped by the comparatively warmer spring atmosphere, could help in augmenting plant growth and development.

Interesting pot culture and field experiment were conducted by Krzyech and Eberhardt (1960) to prevent spring barley or winter wheat from the mildew disease caused by _Erysiphe graminis_ by spraying the leaves with weak solutions of salts of phosphorus, nitrogen or potassium singly or in various combinations. They reported that these exhibited a prophylactic action with the exception of urea. Higher yields of grain, straw and crude protein were also obtained by these protective treatments. These observations are not unexpected as it is well established that vigorously growing plants would always be in a better position to combat disease-causing organisms and foliar nutrition would certainly help the treated plants grow better.

While reviewing the pathways and mechanism of penetration of foliar applied solutions, Franke (1967) discussed the relative roles of stomata, cuticle, cell wall and plasma membranes. He came to the conclusion that the overall process of penetration took place in three stages. In the first, substances supplied to the leaf surface penetrated the cuticle and epidermal cell wall via a limited or free surface. In the second, these substances having penetrated the free space, were adsorbed to the surface of the plasma membrane by some form of binding. In the third and final stage, the adsorbed substances were taken up into the cytoplasm in a process requiring metabolically derived energy (active uptake). This was supported by studies of the Q_{10} of absorption, the effect of respiratory inhibitors on the process, by the time-course studies of uptake, as well as studies of foliar excretion, a process which was just the reverse of uptake.

De (1971) reviewed the work done in India on the foliar fertilisation of crops. About mustard he remarked that combination of insecticides with fertiliser material like urea could enhance the yield of the crop. His own data revealed that mustard yield was considerably increased if nitrogen was supplied partly through the roots and partly through the leaves. Two combinations (40+40 or 60+20 soil: foliar) proved better than the other combinations including the entire dose of 80 kg N / ha added to the soil, not only from the point of view of total yield but also of economic yield recording a net saving of Rs.300 - 400/ha.

Field and laboratory studies were conducted by Nalamwar et al. (1972) to study the effect of soil and foliar application of various doses of phosphorus and nitrogen on yield and composition of ground nut. They noted that application of 22.5 kg P_2O_5 / ha through soil or foliage increased the yield of nuts. The uptake of phosphate was noted to increase progressively until harvest, the percentage in the plant being higher in the phosphate-applied plants as compared with the no- phosphate controls.

A comparative study of the effect of soil- and foliar-applied phosphorus on the yield of barley (Hordeum vulgare) was carried out by Afridi and Samiullah (1973). They concluded that the beneficial effect of spray of phosphorus was more pronounced when the plants had received a small dose of phosphatic fertiliser by basal dressing than when they were grown without soil-applied phosphorus. It may be pointed out here that the range of leaf-applied phosphate was rather limited in this experiment, being based on the dose tried by Silberstein and Wittwer (1951) on tomatoes whereas the phosphate requirements of barley could be totally different.

Khalique (1975) described a sand culture experiment using three high yielding varieties of barley (IB 226, K 572/10 and Rs 6). He treated the plants with two basal treatments (full and half NPK, according to Hewitt, 1966) and seven spray treatments containing nitrogen and phosphorus including a control containing de-ionised water only. His results were generally significant and briefly the findings were:

Growth was significantly enhanced by increasing the strength of the nutrient solution but the effect of various spray treatments was statistically equal to that of spray of water. However, yield characteristics showed optimum response to full nutrient solution supplemented by spray of nitrogen at 8th week after sowing.

Spray of the highest dose of phosphorus on plants grown with full basal nitrogen plus half basal phosphorus gave better yields and produced grain with maximum carbohydrate and protein content.

It is not understandable, however, why the experimental results were not confirmed by a field trial. These same varieties of barley could be grown with equivalent doses of N P K in the form of solid fertiliser, as was done by him in the trials with maize (Experiments 3 and 4).

Qaseem (1975), also working at Aligarh between 1972 and 1974, studied the effect of nitrogenous and phosphatic spray on the yield and grain quality of barley and wheat in three field experiments. He noted that, in barley, spray with phosphorus significantly increased spikelet number and grain number per ear; 1,000 grain weight and grain and straw yield. The ten varieties (which did not include NP13) showed considerable differences amongst them regarding the various yield components listed above.

In the second trial with wheat also, spray of phosphorus increased significantly ear number and ear weight per plant;

spikelet and grain number per year; 1,000 grain weight and grain yield. Like barley, varietal differences in wheat also were very marked among the nine varieties tested.

The last field experiment was performed on six wheat varieties selected as a result of their performance in Experiment 2. Like the earlier experiments on barley and wheat, he found that phosphorus spray had a beneficial effect on yield characteristics and grain quality. Moreover, he noted that the inclusion of nitrogen in the phosphatic spray was found to be more effective.

Although these experiments were planned to study the effect of nutrient spray on yield and grain quality it seems desirable that the effect of nutrients on various growth characters should also have been investigated for the sake of completeness. It is imperative to correlate the effects (nett yield and quality of grain) with the growth history of the plant to obtain a clear-cut picture of the role played by the nutrient through the various stages of its development.

2.3 "Dimecron-100":

The 'rabi' crops in India are invariably infested with aphids and other insects during their most vigorous growing phases - heading/milky grain stages in cereals and flowering/fruiting stages in oil seed crops. Spray of an appropriate insecticide, like "Dimecron-100", has been found to be effective in controlling these pests. The number of insecticide sprays would, of course, depend upon the severity of infestation. Consequently, yields are increased considerably by this remedial method and even the illiterate farmer knows the obvious benefit of such pest control programmes.

"Dimecron-100" is the registered trade mark of phosphamidon produced by M/S Ciba-Geigy Limited, Basle, Switzerland and is freely available in India.

Chemical names: O-[2-chloro-2-(diethyl-carbamoyl)-1-methyl-vinyl]-O,O-dimethyl phosphate

or

O,O-dimethyl-O-(1-methyl-2-chloro-2-diethyl-carbamoyl-vinyl)phosphate

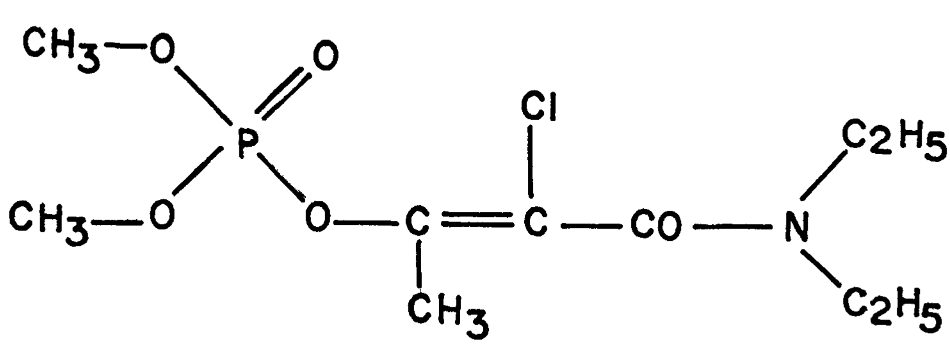
or

O,O-dimethyl-O-(diethylamido-1-chloro-crotonyl-2)phosphate

or

O-(1-chloro-1-diethyl-carbamoyl-1-propen-2-yl)-O,O-dimethyl phosphate

Structural formula:



Empirical formula: $C_{10}H_{19}O_5NClP$

It is freely miscible with water and is compatible with most other insecticides, fungicides and nutrients of neutral reaction (cf. Schenck and Adlerz, 1965, 1966). It is a systemic insecticide containing 10% phosphorus. It is not only soluble in water but also in organic solvents and has a favourable distribution coefficient in oil/water (K = 0.22). Dimecron is, therefore, able to penetrate the epidermis fairly easily without added detergents. For the same reason, it is also recommended for treating oil producing plants (Anonymous, 1967 p. 85 and M/S Ciba-Geigy of India Ltd. -personal communication).

Chapter 3

M A T E R I A L A N D M E T H O D S

C O N T E N T S

3. MATERIAL AND METHODS

3.0. The experiments reported and discussed in this thesis were conducted in the field during the 'rabi' (winter) season of the years 1969-73, in the experimental plots at the Aligarh Muslim University, Botanical Garden , Aligarh, Uttar Pradesh. Barley (*Hordeum vulgare* L.) variety NP13 and mustard(*Brassica juncea* (L.) Czern. & Coss.) Var. Laha-101 were selected for the study on the basis of previous experience (Afridi, unpublished; Safaya, 1971; Samiullah, 1971). Authentic seeds were obtained from the Indian Agricultural Research Institute, New Delhi. Each experiment is described below in detail.

3.1. Experiment 1.

The first field experiment was conducted on a sandy loam soil during the "rabi" (winter) season, 1969-70. The physico-chemical analysis of the soil is given in Table 1.

This experiment was designed to study the comparative effect of leaf-applied and soil-applied phosphorus on the NPK concentration, growth and yield of barley variety NP13. In a split plot design, commercial grade urea at the rate of

Table 1. Physico-chemical characteristics of surface soil of the experimental plot 1969-70 (Experiment 1)

(I)	Texture	Sandy loam
(II)	Particle size distribution	
	Sand %	52.4
	Silt %	38.0
	Clay %	09.6
(III)	pH (1:2)	07.6
(IV)	Conductivity E.C. (m mhos / cm)	01.40
(V)	Available nitrogen (N) (kg / ha)	273.80
(VI)	Available phosphorus (P) (kg / ha)	14.4
(VII)	Available potassium (K) (kg / ha)	1,750.0

60 kg N/ha and muriate of potash at the rate of 30 kg K_2O / ha were applied uniformly to the soil in all plots. In nine plots, monocalcium superphosphate at the rate of 30 kg P_2O_5 / ha was applied in furrows at the time of sowing, the other nine being kept unfertilised with phosphorus. Four doses of one per cent aqueous solution of sodium dihydrogen orthophosphate, containing 1.365 kg P_2O_5 / ha, 2.730 kg P_2O_5 / ha, 5.460 kg P_2O_5 / ha and 10.920 kg P_2O_5 / ha respectively, were sprayed at 70 days (heading stage) or 90 days (milky grain stage) after sowing on plots that had been deprived of basal superphosphate as well as on those that had received this fertiliser. Controls were sprayed with de-ionised water simultaneously in both cases.

The summary of various treatments is given in Table 2. Thus in all there were 18 treatments each with three replications. The size of each plot was 27 sq.m. The seeds were tested for their viability as well as germinability using standard methods. Disease-free and plump seeds of uniform size and weight were selected and treated with "Faradoxon", a commercial fungicide. The usual "behind the plough" method of sowing was adopted. Seeds were sown at the rate of 10 kg / ha. Only 15 seeds were sown per furrow. The furrows were kept 22.5 cm apart. Sowing was done on 15 November, 1969. The field received three irrigations between sowing and harvesting. Weeding was done thrice during the entire course of growth of plants. The crop was harvested on 30 April, 1970. It may be pointed out that

Table 2. Summary of treatments (Experiment 1)

S.No.	Treatments	Basal P_2O_5 applied (kg/ha)	P_2O_5 in spray (kg / ha)	Time of spray (days after sowing)
1.	F_0P_0	Nil	Nil*	Nil*
2.	F_0P_1 (70)	Nil	1.365	70
3.	F_0P_2 (70)	Nil	2.730	70
4.	F_0P_3 (70)	Nil	5.460	70
5.	F_0P_4 (70)	Nil	10.920	70
6.	F_0P_1 (90)	Nil	1.365	90
7.	F_0P_2 (90)	Nil	2.730	90
8.	F_0P_3 (90)	Nil	5.460	90
9.	F_0P_4 (90)	Nil	10.920	90
10.	$F_{30}P_0$	30	Nil*	Nil*
11.	$F_{30}P_1$ (70)	30	1.365	70
12.	$F_{30}P_2$ (70)	30	2.730	70
13.	$F_{30}P_3$ (70)	30	5.460	70
14.	$F_{30}P_4$ (70)	30	10.920	70
15.	$F_{30}P_1$ (90)	30	1.365	90
16.	$F_{30}P_2$ (90)	30	2.730	90
17.	$F_{30}P_3$ (90)	30	5.460	90
18.	$F_{30}P_4$ (90)	30	10.920	90

* Sprayed with de-ionised water only at 70 and 90 days after sowing.

the crop was subjected to a very serious frost from 21.1.1970 to 25.1.1970, and a severe hailstorm on 27.4.1970, just before harvest.

3.2. Experiment 2.

The second field experiment was performed in the same field during the 'rabi' season, 1971-72. The physico-chemical analysis of the soil is given in Table 3. This experiment was designed to study the effect of various doses of leaf-applied phosphorus with and without "Dimecron-100", an insecticide, sprayed once at 70 days (heading stage) or twice at 70 and 90 days (milky grain stage) on the NPK concentration in leaves of barley and on its growth and yield characteristics.

In a simple randomised block design, commercial grade urea at the rate of 60 kg N / ha was applied in furrows at the time of sowing. Various doses of 1 per cent sodium dihydrogen orthophosphate with and without 0.02 per cent "Dimecron-100", were sprayed on the leaves in the form of aqueous solution.

The treatments given are summarised in Table 4. Thus in all there were 10 spray treatments, each replicated thrice. The size of each treated plot was 27 sq.m. Seeds were tested for their viability and germinability and were found to be of good quality. Uniform-sized, plump and healthy looking seeds were surface-sterilised before sowing which was done by drilling

Table 3. Physico-chemical characteristics of surface soil of the experimental plot 1971-72 (Experiments 2 and 3)

(I)	Texture	Sandy loam
(II)	Particle size distribution	
	Sand %	52.4
	Silt %	38.0
	Clay %	09.6
(III)	pH (1:2)	08.4
(IV)	Conductivity E.C. (m mhos)	00.30
(V)	Available nitrogen (N) (kg / ha)	241.04
(VI)	Available phosphorus (P) (kg / ha)	11.2
(VII)	Available potassium (K) (kg / ha)	1,325.0

method. The seed rate was 10 kg/ha. Rows were kept at a distance of 22.5 cm apart from each other. The date of sowing was 25 November, 1971. The field required three irrigations during the course of development. Weeding was done as required. The crop was harvested on 19 April, 1972.

3.3. Experiment 3.

The third experiment was conducted on a field adjacent to the one used for Experiment 3 during the 'rabi' season, 1971-72. The physico-chemical analysis of the soil was the same as in Experiment 2.

Mustard Var. Laha-101 was selected to study the effect of ten doses of leaf-applied phosphorus and "Dimecron-100" in various combinations sprayed once (at 70 days after sowing) and twice (at 70 and 90 days after sowing) on the NPK concentration in the leaves, length of plant, yield of seeds and percentage of oil and protein in the seeds. In a simple randomised block design, commercial grade urea at the rate of 60 kg N/ha was applied to the soil as mentioned in experiment 2. Spray treatments are listed in Table 4. Thus the design consisted of 10 treatments each with three replications. The size of each plot was 27 sq.m. The seeds were tested prior to sowing for their viability and germinability using standard methods. Healthy seeds were surface-sterilised and sown by the usual 'behind the

Table 4. Summary of treatments (Experiment 2 and 3)

S.No.	Treatments	P_2O_5 in spray (kg / ha)	Dimecron in spray (1 / ha)	Time of spray (days after sowing)
1.	P_0D_0	Nil	Nil	Nil (sprayed with water)
2.	P_0D	Nil	0.74	70
3.	P_1D_0	1.365	Nil	70
4.	P_2D_0	2.730	Nil	70
5.	P_3D_0	5.460	Nil	70
6.	P_1D	1.365	0.74	70
7.	P_2D	2.730	0.74	70
8.	P_3D	5.460	0.74	70
9.	2 x P_1D_0	1.365	Nil	70 and 90
10.	2 x P_1D	1.365	0.74	70 and 90

plough' method, at the rate of 1.9 kg/ha in uniform rows (22.5 cm apart from each other). The field required three irrigations between sowing (30 November, 1971) and harvesting (22 April, 1972). Weeding was done when required.

3.4. Experiment 4.

The fourth experiment was carried out on the same field used for Experiments 2 and 3 during the 'rabi' season, 1973-74. The physico-chemical analysis of the soil of the field is given in Table 5.

The aim of this experiment was to study the effect of foliar-applied phosphorus as well as sulphur, singly and in combination, on the NPK concentration, growth, yield of seeds and percentage of oil and protein in the seeds of mustard grown with three doses of basal phosphorus.

In a factorial randomised block design, commercial grade urea at the rate of 60 kg N/ha and muriate of potash at the rate of 40 kg K_2O /ha were applied as basal dressing to all the plots. In addition, four treatments included monocalcium superphosphate at the rate of 20 kg P_2O_5 / ha and another four, 40 kg P_2O_5 / ha. The remaining four treatments had no basal dressing of phosphate. The fertilisers were applied in furrows at the time of sowing.

Table 5. Physico-chemical characteristics of surface soil of the experimental plot 1973-74 (Experiment 4)

(I)	Texture	Sandy loam
(II)	Particle size distribution	
	Sand %	52.4
	Silt %	38.0
	Clay %	09.6
(III)	pH (1:2)	08.5
(IV)	Conductivity E.C. (m mhos / cm)	00.35
(V)	Available nitrogen (N) (kg / ha)	241.04
(VI)	Available phosphorus (P) (kg / ha)	05.6
(VII)	Available potassium (K) (kg / ha)	1,500.0

To the leaves, 1.0% sodium dihydrogen orthophosphate (2 kg P_2O_5 / ha) and 1.0% sodium sulphate (1 kg S/ha) were sprayed in the form of aqueous solutions alone or together. The sprays were applied consecutively at the flowering and fruiting stages. Controls were sprayed with de-ionised water only.

The schedule of various treatments is listed in Table 6. Thus in all there were 12 treatments, each replicated thrice. The size of each plot was 10 sq.m. The selection and treatment of seeds before sowing was done as in previous experiments. Seeds were sown in drills at the rate of 5 kg/ha. The distance between furrows was 22.5 cm. The sowing was done on 12 November, 1973. Four irrigations were given during the course of growth. Weeding was done whenever required. The crop was harvested on 6 April, 1974.

3.5. Sampling Technique

3.5.1. BARLEY

To study the nutrient status, growth characters and yield of barley, random sampling of five plants was carried out 10 days after spraying the plants at the well known heading and milky grain stage, and at the time of harvest. In addition, the total yield of each plot was also taken and its straw and grain components determined.

Table 6. Summary of treatments (Experiment 4)

S.No.	Treatments	Basal P_2O_5 (kg / ha)	P_2O_5 / S in each spray*
1	F_0W	Nil	Nil (sprayed with water)
2	F_0P	Nil	2 kg P_2O_5 / ha
3	F_0S	Nil	1 kg S / ha
4	F_0PS	Nil	2 kg P_2O_5 plus 1 kg S / ha
5	F_1W	20	Nil (sprayed with water)
6	F_1P	20	2 kg P_2O_5 / ha
7	F_1S	20	1 kg S / ha
8	F_1PS	20	2 kg P_2O_5 plus 1 kg S / ha
9	F_2W	40	Nil (sprayed with water)
10	F_2P	40	2 kg P_2O_5 / ha
11	F_2S	40	1 kg S / ha
12	F_2PS	40	2 kg P_2O_5 plus 1 kg S / ha

* The two sprays were applied at 70 and 90 days after sowing.

3.5.1.1. Growth characteristics:

To assess the effect of phosphorus applications, to the soil and leaves, such characteristics of growth were chosen which would throw light on some fundamental physiological processes. The following growth characteristics were studied according to recommended procedure, 10 days after each spray:

(i) Tiller number
(ii) Fresh weight
(iii) Dry weight

Whereas the fresh weight and dry weights would account for the total productivity in terms of rate of increase in weight, volume and dry matter accumulation, tiller number would be a measure of meristematic activity.

3.5.1.2. Yield characteristics:

In Experiments 1-4, plants were allowed to grow to maturity. The following yield characteristics were studied at the time of harvest:

(i) Ear number per plant
(ii) Ear weight per plant
(iii) Length per ear
(iv) Spikelet number per ear

(v) Grain number per ear

(vi) Weight of 1,000 grains

(vii) Total yield of plants per hectare

(viii) Grain yield per hectare

(ix) Straw yield per hectare

3.5.2. MUSTARD

To measure the NPK concentration and growth characters in mustard, randomised sampling of five plants was done 10 days after each spray. At harvest, the total weight of seeds per plot was taken and samples were kept for determining the percentage of oil and protein in seeds.

3.5.2.1. Growth characteristics

The following growth characteristics were studied:

(i) Shoot length

(ii) Fresh weight

(iii) Dry weight

3.5.2.2. Yield characteristics

At harvest, the seeds of plants of individual plots were taken out and weighed separately. Samples of seeds were kept for the analysis of protein and oil contents.

3.5.3. Nutrient content:

Data about the following were obtained by leaf analysis in both crops:

(i) Percentage of nitrogen concentration in leaves
(ii) Percentage of phosphorus concentration in leaves
(iii) Percentage of potassium concentration in leaves

3.6. LEAF ANALYSIS

The five sample plants in each treatment were wiped free of any adhering dust. Roots were severed and fresh weight taken. The samples were dried for 24 hours in an oven at 80°C. Dry weight of the samples was taken the next day. Fully mature and expanded leaf blades were detached from the shoots, finely powdered and passed through a 72 mesh screen. The powder was stored in screw-capped polythene vials, labelled and kept for analysis.

The leaf powder was kept at 70°C overnight before being digested and analysed for its NPK content according to the method of Lindner (1944), with slight modifications.

100 mg of the dried leaf powder of each sample was weighed and carefully transferred to a 50 ml Kjeldahl flask. It was wet ashed in 2 ml of chemically pure sulphuric acid. To allow for complete reduction of nitrates present in the plant

material by the organic matter itself, digestion was continued for about two hours. Dense fumes were given off at this stage and the contents turned black. The flasks were cooled for 15 minutes. After cooling, 0.5 ml of chemically pure 30 per cent hydrogen peroxide was added dropwise and the solution was heated again till the colour of solution changed from black to light yellow. After heating for about 30 minutes the flasks were kept for cooling for 10 minutes and to get the extracts clear and colourless 3 or 4 additional drops of 30 per cent hydrogen peroxide were added in like manner followed by gentle heating for about 15 minutes. Care was taken in the addition of hydrogen peroxide because its excess might oxidise the ammonia in the absence of organic matter. The digested peroxide material was diluted with double distilled water and transferred with 3 or 4 washings to 100 ml volumetric flasks and volumes made up with distilled water. Corresponding aliquots for determining nitrogen phosphorus and potassium, were taken from these sulphuric acid-peroxide digested samples. The methods employed for estimation of these elements are briefly described below:

3.6.1. Nitrogen. The nitrogen content of the samples was estimated according to Lindner (1944). A 10 ml aliquot of the peroxide digested material was taken in a 50 ml volumetric flask and the excess of acid partially neutralised with 2 ml of 2.5 N sodium hydroxide. 1 ml of 10 per cent sodium silicate was added to prevent turbidity. After making up the volume, a 5 ml aliquot of this solution was taken in a 10 ml graduated test tube and 0.5 ml of Nessler's reagent was added drop by drop, mixing thoroughly after the addition of each drop. Distilled water was added to make the volume upto 10 ml and the contents were allowed to stand for 5 minutes for maximum colour development. The solution was then transferred to a colorimetric tube and the optical density measured at 525 nm using a Bausch and Lomb "Spectronic 20" colorimeter. A blank was run with each set of determinations and the amount of nitrogen in the aliquot was read from a calibration curve, obtained using known dilutions of a standard ammonium sulphate solution, which followed Beer's Law.

3.6.2. Phosphorus. Total phosphorus in the sulphuric acid-peroxide digest was estimated by the method of Fiske and Subba Row (1925). A 5 ml aliquot was taken in a 10 ml graduated tube and 1 ml molybdic acid (2.5% ammonium molybdate in 10N H_2SO_4) was added with care followed by 0.4 ml of 1,2,4 aminonaptha sulphonic acid. The colour turned to blue. Distilled water was then added to the blue solution to make the volume upto 10 ml. The solution was mixed thoroughly, kept to stand for 5 minutes and then transferred to a colorimetric tube. The optical density was read at 620 nm with the help of a "Spectronic 20" colorimeter. A blank was run for each determination. The standard curve was prepared by using known concentrations of monobasic potassium phosphate solution.

3.6.3. Potassium. Potassium was estimated flame photometrically. One ml aliquot was taken and read at 768 nm. A blank was run side by side. The readings were compared with calibration curve plotted for different dilutions of a standard potassium sulphate solution.

3.7. SEED ANALYSIS

Seeds were analysed to assess their oil and total protein content. Oil was extracted from the seeds after crushing them. For protein analysis, whole seeds were cleaned, dried overnight at 80°C and powdered.

3.7.1. Oil extraction and estimation. Crushed Laha seeds weighing 5.0 g were transferred to a Soxhlet extraction apparatus to which sufficient quantity of pure petroleum ether was added. The apparatus was kept in a hot water bath running at 60°C for 7 h for complete extraction of oil. The petroleum ether containing the extracted oil was then kept in open air to evaporate off the ether. The remaining oil was weighed and the percentage of oil in the seeds, as well as total oil yield, calculated.

3.7.2. Total protein estimation. Sufficient amount of seed powder was spread over a sheet of paper and dried overnight in an oven running at 80°C. The dried samples were cooled in a dessicator for about 5 min before weighing. 50 mg of each sample was weighed and transferred to a mortar. One ml of cold 5 per cent trichloroacetic acid was added to it. The powder was ground well and then transferred to a centrifuge tube with repeated washings and the volume made up to 5 ml with trichloroacetic acid and kept for about 1 h to allow the complete precipitation of proteins (Yih and Clark , 1965). The samples were then centrifuged at 4,000 rpm for 15 min and the supernatant was discarded. To the residue, 5 ml of 1.0N sodium hydroxide was added and shaken well for complete mixing. It was kept for half an hour on a water bath running at 60°C so as to dissolve the precipitated proteins completely. After cooling for 15 min, the mixture was centrifuged at 4,000 rpm for 15 min and the supernatant was discarded. To the residue, 5 ml of 1.0N sodium hydroxide was added and shaken well for complete mixing. It was kept for half an hour on a water bath running at 60°C so as to dissolve the precipitated proteins completely. After cooling for 15 min, the mixture was centrifuged at 4,000 rpm for 15 min and the supernatant containing the protein fractions was collected. It was then diluted with appropriate quantity of water. An aliquot measuring 1.0 ml of this diluted fraction was taken in a test tube for protein estimation. The following three reagents, from amongst those included in the original publication of Lowry *et al.* (1951), and required for total protein estimation were prepared and used for this purpose.

Reagent B: 0.5 per cent copper sulphate in 1 per cent sodium tartrate in the ratio of 1:1.

Reagent D: (carbonate-copper sulphate solution): 50 ml of 2 per cent sodium carbonate plus 1 ml of reagent B.

Reagent E: (diluted folin reagent): Folin-ciocalteu reagent diluted to make it 1.0 N in acid prepared as given below:

100 g of sodium tungstate and 25 g of sodium molybdate were dissolved in 700 ml of water and kept in a 1,500 ml flask. 50 ml of 85 per cent phosphoric acid and 100 ml of concentrated hydrochloric acid were then added. The flask was connected with a reflux condenser and boiled gently on a heating mantle for 10 h. At the end of the boiling period, 150 g lithium sulphate, 50 ml water and three to four drops of liquid bromine were added to the flask. The reflux was removed and the solution in the flask boiled for 15 min to remove excess bromine, cooled and diluted to 1,000 ml.

The strength of this acidic solution was estimated by titrating it with 1.0 N solution of sodium hydroxide using phenolphthalein as an indicator. It was then diluted to give the required strength (1.0 N).

To the 1.0 ml of collected protein fraction 5 ml of reagent was added. After exactly 10 min, 0.5 ml of Reagent B was added and left for half an hour for the development of full colour. The transmittance of the samples was noted at 660 nm on Bausch and Lomb 'Spectronic 20' Colorimeter. A blank was run simultaneously with every set of sample. The reading of each sample was compared with a calibration curve, obtained by using known dilutions of a standard egg albumen solution, which followed Beer's law.

3.8. Statistical analysis.

All data were analysed statistically with reference to the design of each experiment according to Panse and Sukhatme (1954). The most rigorous "F" tests were followed in which the error due to replicates was also determined. When "F" value was found to be significant at the 5 per cent level of probability, critical difference (C.D.) was also calculated. The models of the analysis of variance (ANOVA) for each of the experimental design are given in Table 7.

Table 7. Models of the Analysis of Variance

Split Plot Design (Experiment 1)

Source of variation	D.F. (heading stage)	D.F. (milky grain stage)	S.S.	M.S.	F.
Replication	2	2			
Main plot treatments	4	8			
Error (a)	8	16			
Split plot treatments	1	1			
Split plot treatments x Main plot treatments	4	8			
Error (b)	10	18			
Total	29	53			

Simple Randomised Block Design (Experiments 2 and 3)

Source of variation	D.F.	S.S.	M.S.	F.
Replication	2			
Treatments	9			
Error	18			
Total	29			

Factorial Randomised Design (Experiment 4)

Source of variation	D.F.	S.S.	M.S.	F.
Replication	2			
Spray treatments	3			
Basal dressings	2			
Spray treatments X basal dressings	6			
Error	22			
Total	35			

Chapter 4

EXPERIMENTAL RESULTS

CONTENTS

4. EXPERIMENTAL RESULTS

4.0. Objective:

The data presented in this chapter were collected to assess the effect of nutrients on growth and yield of barley and mustard. The parameters of growth were selected for barley according to Gregory (1937). They included (i) tiller production- a direct measure of meristematic activity, (ii) fresh and dry weight - a measure of the process of accumulation of dry matter and (iii) leaf NPK content - a measure of total uptake and distribution of these major nutrients.

Among the yield characteristics of barley, final weight of grain and straw, of course, are of the greatest importance. It must, however, be realised that these depend, in one way or the other, on the growth characteristics, including nutrient content on the one hand and on ear characteristics, on the other. It is, therefore, highly desirable to note, at different stages of plant growth, the effect of various regimes of nutrients on ear characteristics contributing to final yields. Thus, ear number, length and weight: spikelet and grain number and test weight, among the yield characteristics would be the major contributing factors (Yoshida, 1972).

A proper compromise among these characteristics (due to severe competition for space and assimilates among the various parts of the panicle) would ensure high yield as determined by the "yield capacity" i.e. (number of panicle per m^2 of land) x (number of spikelet per panicle) x (number of grain per spikelet) x (potential size of grain) as emphasised, among others, by Yoshida (1972).

In mustard, plant height, fresh and dry weight, seed, oil and protein yield as well as oil and protein content of the seed were recorded. As the treatments and/or crop differed from experiment to experiment these are treated separately below:

4.1. Experiment 1:

In this field experiment, the effect of phosphorus, applied to the leaves and roots, on growth and yield characteristics, as well as NPK content of leaves, of NP13 variety of barley was studied. The experiment was based on a split plot design. There were nine main plots and two sub plots, comprising nine levels of foliar spray treatments and two levels of basal dressing of fertilisers, respectively (see p. 34). The data are breifly described below and are summarised in Tables 8 to 28.

4.1.1. <u>Growth characteristics</u>:

Growth characteristics, studied at two stages, i.e. heading stage and milky grain stage, included tiller number per plant and fresh weight and dry weight of five plants (Tables 8 to 13).

4.1.1.1. <u>Tiller number</u>. Tiller number per plant was significantly affected by phosphorus applied as foliar spray, as well as by its basal dressing, at both stages of growth. The difference between two treatment means at the same level of spray or basal treatment was also significant (Tables 8 and 9).

At heading stage, the effect of only five of the nine main plot treatments could be observed. Spray treatment gave significant increase in tiller number over the control. Maximum tiller number (31.5 per cent more than control) was recorded in the treatment $P_1(70)$. The value for this treatment differed critically from that of all other treatments which themselves differed critically from each other. $P_2(70)$ produced the next best number of tillers per plant.

It was noted that tiller production was significantly enhanced (11.7 per cent) as a result of basal application of 30 kg P_2O_5 / ha (P_{30}) over the control (P_0), grown without any basal phosphorus.

Table 8. Effect of foliar and soil application of phosphorus at heading stage on tiller number per plant in NP 13 barley

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (F_0)	30 kg P_2O_5/ha (F_{30})	Mean
	<u>Mean of three replicates</u>		
1. P_0	16.00	18.93	17.46
2. P_1 (70)	21.26	24.66	22.96
3. P_2 (70)	19.93	22.93	21.43
4. P_3 (70)	18.73	19.40	19.06
5. P_4 (70)	20.06	21.40	20.73
Mean	19.20	21.46	

C.D. for main plot treatment at 5% = 1.80

C.D. for sub plot treatment at 5% = 0.50

C.D. for the difference of the main plot means at the same level of sub plot = 1.13

C.D. for the difference of the sub plot means at the same level of main plot = 1.13

Table 9. Effect of foliar and soil application of phosphorus at milky grain stage on tiller number per plant in NP 13 barley

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	31.86	34.86	33.36
2. P_1 (70)	36.40	37.60	37.00
3. P_2 (70)	33.20	37.80	35.50
4. P_3 (70)	41.40	42.00	41.70
5. P_4 (70)	41.66	44.20	42.93
6. P_1 (90)	33.33	36.10	34.71
7. P_2 (90)	37.73	39.60	38.66
8. P_3 (90)	40.20	39.00	39.60
9. P_4 (90)	40.46	42.90	41.68
Mean	37.36	39.34	

C.D. for main plot treatment at 5% = 0.83

C.D. for sub plot treatment at 5% = 0.42

C.D. for the difference of main plot means at the same level of sub plot = 1.23

C.D. for the difference of sub plot means at the same level of main plot = 1.27

Regarding the differences of five main plots at the same level of two sub plots, it was recorded that at 0 kg P_2O_5 / ha level of basal P_2O_5 dressing, $F_0P_1(70)$ produced more tillers as compared with all the other combinations. The next best treatments were $F_0P_4(70)$ and $F_0P_2(70)$ which were equal in their effect. Similarly, at 30 kg P_2O_5 / ha, treatment $F_{30}P_1(70)$ gave the highest value differing critically from the rest of the combinations. Next in order of effectiveness was the treatment $F_{30}P_2(70)$, whereas the poorest response was for the treatments $F_{30}P_3(70)$ and $F_{30}P_0(70)$, which showed equal effect.

When the values for the difference of two sub plot means at the same level of main plots were taken into consideration, it was noted that all the sub plots, receiving 30 kg P_2O_5 / ha as basal dressing, produced more tillers per plant than those receiving 0 kg P_2O_5 / ha, but the two did not differ critically from each other in this respect.

At milky grain stage, maximum value for tiller number was recorded for the spray treatment $P_4(70)$ giving 28.6 per cent increase over control, P_0. It may be added that $P_3(70)$ and $P_4(90)$, which gave slightly lower values for tillers per plant, did not show critical difference from each other.

The basally placed 30 kg P_2O_5 / ha was significantly superior for tiller production and gave 5.4 per cent increase over the control (0 kg P_2O_5 / ha).

Regarding the values for the differences of nine main plot means at the same level of sub plots, it was noted that at 0 level of basal P_2O_5, the treatments $F_0P_4(70)$, $F_0P_3(70)$ and $F_0P_4(90)$ showed equally high effect with F_0P_0 producing the minimum number of tillers. At 30 kg P_2O_5 /ha, maximum tillers were obtained by the treatment $F_{30}P_4(70)$. Next in order were the treatments $F_{30}P_4(90)$ and $F_{30}P_3(70)$ which had equal effect. Like F_0P_0, the treatment $F_{30}P_0$, receiving water only in the spray, was poorest in its effect on the number of tillers per plant.

The values for the difference of two sub plot means at the same level of main plots showed that all the treatments, except $P_3(90)$, produced more tillers at 30 kg P_2O_5 / ha as compared with 0 kg P_2O_5 / ha. The critical difference was noted among the effect of all the treatment pairs (same spray treatment at both the basal level), except $F_0P_1(70)$, $F_0P_3(70)$ and $F_0P_3(90)$ and their counterparts i.e. $F_{30}P_1(70)$, $F_{30}P_3(70)$ and $F_{30}P_3(90)$.

4.1.1.2. <u>Fresh weight</u>. The effect of spray treatments, and of the interaction between basal and spray treatments on fresh weight, was found to be significant at both stages. However, basal dressing gave significant effect on fresh weight only at milky grain stage. The data are presented in Tables 10 and 11.

Table 10. Effect of foliar and soil application of phosphorus at heading stage on fresh weight per five plants in NP 13 barley (g)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	694.20	710.06	702.13
2. P_1 (70)	723.20	869.63	796.41
3. P_2 (70)	897.30	749.56	823.43
4. P_3 (70)	940.13	791.16	865.65
5. P_4 (70)	826.30	1094.86	960.58
Mean	816.22	843.06	

C.D. for main plot treatment at 5% = 83.50

C.D. for sub plot treatment at 5% = N.S.

C.D. for difference of the main plot means at the same level of sub plot = 129.24

C.D. for the difference of the sub plot means at the same level of main plot = 139.54

N.S. Non-significant.

Table 11. Effect of foliar and soil application of phosphorus at milky grain stage on fresh weight per five plants in NP 13 barley (g)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
1. P_0	1229.83	1521.86	1375.85
2. P_1 (70)	1263.10	1769.80	1516.45
3. P_2 (70)	1357.96	1412.46	1385.21
4. P_3 (70)	1407.53	1591.03	1499.28
5. P_4 (70)	1600.06	1854.46	1727.26
6. P_1 (90)	1284.66	1320.13	1302.40
7. P_2 (90)	1375.26	1459.43	1417.35
8. P_3 (90)	1426.16	1552.16	1489.16
9. P_4 (90)	1665.20	1674.63	1669.91
Mean	1401.08	1572.88	

C.D. for main plot treatment at 5% = 1.01

C.D. for sub plot treatment at 5% = 0.61

C.D. for the difference of main plot means at the same level of sub plot = 1.65

C.D. for the difference of sub plot means at the same level of main plot = 1.85

Regarding spray treatments, at heading stage, a gradual increase in fresh weight was noted from the control(P_0), sprayed with water to $P_4(70)$, the highest dose of phosphorus which showed 36.8 per cent increase over the control, P_0. It may be noted that the three remaining spray treatments $P_1(70)$, $P_2(70)$ and $P_3(70)$ showed equal effect.

On comparing the values for the five main plot means at the same level of sub plots, it was noted that $F_{30}P_1(70)$ and and $F_{30}P_4(70)$ gave significantly higher values than their counterparts, $F_0P_1(70)$ and $F_0P_4(70)$ respectively. On the other hand, $F_0P_2(70)$ and $F_0P_3(70)$ gave significantly higher values than the values recorded for $F_{30}P_2(70)$ and $F_{30}P_3(70)$.

When the differences in the values for sub plot means at the same level of main plots were taken into consideration, it was noted that, at 0 kg P_2O_5 / ha level, treatment $F_0P_3(70)$ gave the maximum value, differing critically from F_0P_0 and $F_0P_1(70)$ and showing equal effect with $F_0P_2(70)$ and $F_0P_4(70)$. On the other hand, at 30 kg P_2O_5 / ha basal dressing, it was noted that $F_{30}P_4(70)$ gave the maximum value. The rest of the treatments showed equal effect.

At milky grain stage, the maximum fresh weight (32.6 per cent more than the control) was noted for the spray treatment $P_4(70)$ and the minimum value for the treatment $P_1(90)$, all the spray treatments differing critically from each other.

Regarding the basal treatments, it was noted that F_{30}(30 kg P_2O_5 / ha) was superior in effect to its control, F_0, i.e. 0 kg P_2O_5 / ha, the increase in fresh weight being 12.2 per cent.

The values for the differences of the nine main plot means at the same level of sub plots showed that at 0 kg P_2O_5/ ha, the treatment F_0P_4(90) gave the maximum value whereas, the treatment F_0P_0 was poorest in its effect. All the treatments showed critical difference in their values. At 30 kg P_2O_5 / ha level of P_2O_5, the treatment $F_{30}P_4$(70) was best in its effect, whereas, the treatment $F_{30}P_1$(90) produced minimum fresh weight. It may be added that all values differed critically from each other.

Taking into consideration the values for the difference of the two sub plot means at the same level of the nine main plots, it was noted that all the treatments, at 30 kg P_2O_5 / ha basal dressing, were superior in their response as compared with their counterparts at 0 kg P_2O_5/ha. All the treatments differed critically from each other.

4.1.1.3. <u>Dry weight</u>. Dry weight of five plants, at heading stage and milky grain stage, was significantly affected by various spray and basal treatments. The interaction effect between foliar and soil treatments was also found to be significant (Tables 12 and 13).

Table 12. Effect of foliar and soil application of phosphorus at heading stage on dry weight per five plants in NP13 barley (g)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
1. P_0	132.28	139.50	135.85
2. P_1 (70)	136.86	201.23	169.05
3. P_2 (70)	152.26	146.53	149.40
4. P_3 (70)	157.65	153.73	155.70
5. P_4 (70)	153.83	157.83	155.83
Mean	146.56	159.76	

C.D. for main plot treatment at 5% = 12.22

C.D. for sub plot treatment at 5% = 10.10

C.D. for the difference of the main plot means at the same level of sub plot = 20.12

C.D. for the difference of the sub plot means at the same level of main plot = 22.60

Table 13. Effect of foliar and soil application of phosphorus at milky grain stage on dry weight per five plants in HP 13 barley (g)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
1. P_0	267.03	329.43	298.23
2. P_1 (70)	319.76	340.70	330.23
3. P_2 (70)	347.30	350.00	348.65
4. P_3 (70)	356.73	389.23	372.98
5. P_4 (70)	375.60	451.80	413.70
6. P_1 (90)	302.20	334.26	318.23
7. P_2 (90)	341.40	353.36	347.38
8. P_3 (90)	345.46	361.80	353.63
9. P_4 (90)	316.50	386.46	351.48
Mean	330.22	366.34	

C.D. for main plot treatment at 5% = 2.39

C.D. for sub plot treatment at 5% = 0.86

C.D. for the difference of main plot means at the same level of sub plot = 3.01

C.D. for the difference of sub plot means at the same level of main plot = 2.59

Considering the spray treatments, at heading stage, it was noted that the treatment $P_1(70)$ gave significant maximum value (24.4 per cent higher than the control, P_0), whereas, treatments $P_4(70)$, $P_3(70)$ and $P_2(70)$ were similar in their influence.

Among soil treatments, F_{30}i.e. 30 kg P_2O_5 / ha was better than the unfertilised control, differing critically from it and showing 9.0 per cent more dry matter production.

Taking into consideration the values for the difference of the five main plot means at the same level of the two sub plots, it was found that, at 0 kg P_2O_5 / ha, $F_0P_3(70)$, $F_0P_4(70)$ and $F_0P_2(70)$ showed equal effect. Similarly, the treatments $F_0P_4(70)$, $F_0P_2(70)$, $F_0P_1(70)$ and F_0P_0 did not differ critically from each other in their effect. At 30 kg P_2O_5 / ha level of basal phosphorus, $F_{30}P_1(70)$ gave significant maximum value, whereas the rest of the treatments were similar in their effect.

Regarding the values for the difference of sub plot means at the same level of main plots, it was found that the treatments $F_{30}P_0(70)$, $F_{30}P_1(70)$ and $F_{30}P_4(70)$ gave higher values as compared with their pairs F_0P_0, $F_0P_1(70)$. However, the treatments $F_0P_2(70)$ and $F_0P_3(70)$ gave higher dry weight than $F_{30}P_2(70)$ and $F_{30}P_3(70)$ respectively, with only treatments

$F_0P_1(70)$ and $F_{30}P_1(70)$ differing critically from each other.

At milky grain stage, spray treatment $P_4(70)$ gave maximum dry matter, being 38.7 per cent more than the control, P_0, followed by $P_3(70)$. Treatments $P_3(90)$ and $P_4(90)$ showed equal effect. Similarly, critical difference was not noted in the effect of treatments $P_2(70)$ and $P_2(90)$ as well as of $P_1(70)$ and $P_1(90)$. P_0, the control, produced minimum dry weight.

Among basal treatments, it was noted that more dry matter was produced with 30 kg P_2O_5 / ha than with the 0 kg P_2O_5 / ha (control), being 10.9 per cent higher in value.

Regarding the values for the difference of the nine main plot means at the same level of the two sub plots, at 0 kg P_2O_5 / ha level, the maximum value was obtained for the treatment $F_0P_4(70)$. The next best treatment was $F_0P_3(70)$. The treatments, $F_0P_2(70)$ and $F_0P_3(90)$ showed equal effect. The remaining treatments i.e. $F_0P_2(90)$, $F_0P_1(70)$, $F_0P_4(90)$, $F_0P_1(90)$ and F_0P_0 differed critically from each other in their effect. At 30 kg P_2O_5 /ha, the best treatment, having significant effect, was $F_{30}P_4(70)$ followed by $F_{30}P_3(70)$ and $F_{30}P_4(90)$, which showed similar effect. The values for the rest of the treatments differed critically from each other. The treatment $F_{30}P_0$ gave the minimum value.

When the values for the difference of two sub plot means at the same level of main plots were taken into consideration, it was noted that all the treatments at 30 kg P_2O_5 / ha gave higher values as compared with their respective counterparts at 0 kg P_2O_5 / ha. The effect of the treatments differed critically from each other.

4.1.2. Yield characteristics:

Yield data are presented in Tables 14 to 22 and are summarised below:

4.1.2.1. Ear number per plant. The number of ears per plant was significantly affected both by phosphorus in spray as well as by its basal dressing. The difference of the main plot values at the same level of sub plot and vice-versa was also significant (Table 14).

Among spray treatments, maximum ear number was obtained by the treatment P_3(90). It was 37.0 per cent more than P_0, the control. The next good treatments were P_4(70), P_4(90) and and P_3(70) alongwith P_2(70), P_1(70) and P_1(90) which showed equal response. The minimum value was recorded in P_0, the control.

Basal application of 30 kg P_2O_5 / ha (P_{30}) was found to be 11.3 per cent better for ear production as compared with

Table 14. Effect of foliar and soil application of phosphorus on ear number per plant in NP 13 barley

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	27.66	29.20	28.43
2. P_1 (70)	32.86	37.06	34.96
3. P_2 (70)	34.26	35.80	35.03
4. P_3 (70)	35.00	36.40	35.70
5. P_4 (70)	34.33	38.93	36.63
6. P_1 (90)	28.93	40.33	34.63
7. P_2 (90)	32.86	33.06	32.96
8. P_3 (90)	35.46	42.46	38.96
9. P_4 (90)	35.13	37.93	36.53
Mean	32.94	36.80	

C.D. for main plot treatment at 5% = 2.23

C.D. for sub plot treatment at 5% = 0.91

C.D. for the difference of the main plot means at the same level of sub plot = 2.95

C.D. for the difference of the sub plot means at the same level of main plot = 2.74

0 kg P_2O_5 / ha (F_0), the values being critically different from each other.

Regarding the values for the difference of the main plot means at the same level of sub plots, it was noted that, at 0 kg P_2O_5 / ha i.e. F_0, the treatments, $F_0P_3(90)$, $F_0P_4(90)$, $F_0P_3(70)$, $F_0P_4(70)$, $F_0P_2(70)$, $F_0P_1(70)$ and $F_0P_2(90)$ were equally superior in their effectiveness. $F_0P_1(90)$ and F_0P_0 produced the least ears per plant. At 30 kg P_2O_5 / ha (F_{30}), the treatment $F_{30}P_3(90)$ and $F_{30}P_1(90)$, being equal in effect, produced significantly more ears as compared with the other treatments. Treatments $F_{30}P_1(90)$, $F_{30}P_4(70)$ and $F_{30}P_4(90)$, being next in order, were similar in their effect. $F_{30}P_0$ was noted to be poorest for the production of fertile ears.

The values for the difference of the sub plot means at the same level of main plots showed that all the spray treatments at F_{30}(30 kg P_2O_5 / ha) generally gave better results as compared with the spray treatments at F_0(0 kg P_2O_5 / ha). However, the values for treatments F_0P_0, $F_0P_2(70)$, $F_0P_3(70)$ and $F_0P_2(90)$ did not differ critically from their respective counterparts.

4.1.2.2. <u>Weight of ears</u>. The weight of ears per plant was found to be significantly affected by foliar as well as basal application of phosphorus in soil. The effect of two combination means at the same level of main and sub plots was also noted to be significant (Table 15).

Regarding spray treatments, it was noted that the treatment P_5(90) and P_1(70) gave the maximum (and equal) value, 39.3 per cent more than the control, P_0. The latter treatment was equal to P_4(90) in its effect. The minimum value was recorded in the water-sprayed control, P_0.

Among soil treatments, higher weight of ears was obtained when the soil was applied with 30 kg P_2O_5 / ha. This effect differed critically from that of 0 kg P_2O_5 / ha, and was 7.9 per cent better.

On considering the differences of nine main plot means at the same level of two sub plots, it was found that at the level of 0 kg P_2O_5 / ha, the treatments F_0P_1(70), F_0P_4(90) and F_0P_5(90) gave higher and equal response as compared with the other treatments, F_0P_0 being the poorest in its effect. At 30 kg P_2O_5 / ha, $F_{30}P_5$(90) gave maximum ear weight followed by the treatments $F_{30}P_1$(70), $F_{30}P_4$(90) and $F_{30}P_2$(70) which had equal but lesser effect. The poorest effect was noted in the treatment $F_{30}P_0$, the control.

When the difference of two sub plot means at the same level of main plots was considered, it was noted that all the treatments gave higher value at 30 kg P_2O_5/ha when compared

Table 15. Effect of foliar and soil application of phosphorus on ear weight per five plants in NP 13 barley (g)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	Sub plot (soil dressing) 30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	221.63	242.40	232.01
2. P_1 (70)	311.36	329.46	320.41
3. P_2 (70)	300.70	320.40	310.55
4. P_3 (70)	275.53	290.93	283.23
5. P_4 (70)	280.66	290.90	285.78
6. P_1 (90)	235.16	293.46	264.31
7. P_2 (90)	287.43	293.36	290.40
8. P_3 (90)	302.43	344.33	323.38
9. P_4 (90)	311.13	321.33	316.23
Mean	280.67	302.95	

C.D. for the main plot treatment at 5% = 6.22

C.D. for the sub plot treatment at 5% = 3.13

C.D. for the difference of the main plot means at the same level of sub plot = 9.13

C.D. for the difference of the sub plot means at the same level of main plot = 9.45

with their respective counterparts at 0 kg P_2O_5 / ha. Critical difference was recorded between all the pairs of sub plots at both the levels of soil-applied phosphorus, except in $P_4(90)$ at 0 kg and 30 kg P_2O_5 / ha.

4.1.2.3. Length per ear. The effect of leaf-applied phosphorus on ear length was found to be non-significant. Whereas, the effect of basal application of phosphorus as well as the differences of main plot means at the same level of sub plots and vice-versa were noted to be significant. The results are shown in Table 16.

Basal dressing of phosphorus at the rate of 30 kg P_2O_5/ha proved to be better in promoting the length of ears as compared with 0 kg P_2O_5/ha. The effect of these treatments differed critically from each other.

When the values for the main plot treatments were compared with each other at the same level of sub plot treatments, it was found that at 0 kg P_2O_5 / ha, $F_0P_2(90)$, $F_0P_4(90)$, $F_0P_3(70)$, $F_0P_1(70)$, $F_0P_3(90)$ and $F_0P_4(70)$ produced similar effect. At 30 kg P_2O_5 / ha, the treatments $F_{30}P_4(90)$, $F_{30}P_4(70)$, $F_{30}P_2(70)$, $F_{30}P_1(70)$ and $F_{30}P_3(90)$ showed equal effect. The effect of treatments $F_{30}P_1(90)$ and $F_{30}P_2(90)$ was poorer as compared with that of the control ($F_{30}P_0$).

Table 16. Effect of foliar and soil application of phosphorus on length per ear in NP 13 barley (cm)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	13.82	14.22	14.02
2. P_1 (70)	14.38	15.21	14.79
3. P_2 (70)	12.92	15.37	14.14
4. P_3 (70)	14.78	14.52	14.65
5. P_4 (70)	14.22	15.46	14.84
6. P_1 (90)	13.67	13.70	13.69
7. P_2 (90)	14.95	13.26	14.10
8. P_3 (90)	14.32	14.70	14.51
9. P_4 (90)	14.94	16.09	15.51
Mean	14.22	14.72	

C.D. for the main plot treatment at 5% = N.S.

C.D. for the sub plot treatment at 5% = 0.44

C.D. for the difference of main plot means at the same level of sub plot = 1.52

C.D. for the difference of sub plot means at the same level of main plot = 1.32

N.S. Non - significant

Regarding the values for the difference of sub plot means at the same level of main plots, the treatment $P_0P_3(70)$ and $P_0P_2(90)$ gave better results than their respective counterparts $P_{30}P_3(70)$ and $P_{30}P_2(90)$. Whereas, all other spray treatments showed better effect at 30 kg P_2O_5 / ha than 0 kg P_2O_5 / ha. critical difference was noted only in the treatments $P_0P_2(70)$ and $P_0P_4(90)$ when compared with their respective counterparts $P_{30}P_2(70)$ and $P_{30}P_4(90)$ at 30 kg P_2O_5 / ha.

4.1.2.4. Spikelet number per ear. The effect of foliar application and basal dressing of phosphorus on the number of spikelets was found to be significant. The interaction was not found to be significant. The data are listed in Table 17.

Among spray treatments, $P_4(70)$ and $P_4(90)$ gave maximum value, being 17.8 per cent higher than that for P_0. On the other hand, the treatments $P_4(90)$, $P_3(90)$, $P_1(70)$, $P_2(70)$ and $P_3(70)$ were similar in their effect. P_0, the control, produced the minimum number of spikelets but its effect was equal to other treatments except $P_4(70)$ and $P_4(90)$.

Phosphorus at the level of 30 kg P_2O_5 / ha as basal fertiliser produced 4.7 per cent more spikelets per ear than did 0 kg P_2O_5 / ha. The effect of the two levels differed critically from each other.

Table 17. Effect of foliar and soil application of phosphorus on spikelet number per ear in RD 13 barley

Main plot	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	14.23	16.53	15.38
2. P_1 (70)	16.00	17.60	16.80
3. P_2 (70)	15.86	17.60	16.73
4. P_3 (70)	16.00	16.46	16.23
5. P_4 (70)	17.26	19.00	18.13
6. P_1 (90)	15.66	15.93	15.80
7. P_2 (90)	16.33	15.26	15.80
8. P_3 (90)	17.06	16.66	16.86
9. P_4 (90)	17.13	17.33	17.23
Mean	16.17	16.93	

C.D. for the main plot treatment at 5% = 1.15

C.D. for the sub plot treatment at 5% = 0.56

C.D. for the difference of main plot means at the same level of sub plot = N.S.

C.D. for the difference of sub plot means at the same level of main plot = N.S.

N.S. Non - significant

4.1.2.5. Grain number per ear. The number of grains per ear was significantly affected both by spray treatments and basal fertilisation with phosphorus. The difference of main plot means at the same level of sub plots and vice-versa was also found to be significant. The results obtained are given in Table 10.

The spray treatments $P_1(90)$, $P_4(70)$ and $P_1(70)$, being equal in their effect, gave 21.6 per cent better results as compared with the other treatments. Minimum number of grains per ear was obtained in the water-sprayed control, P_0. The effect, however, did not differ critically from that of $P_2(90)$.

Basal application of phosphorus at the rate of 30 kg P_2O_5 / ha gave 6.6 per cent higher value than 0 kg P_2O_5 / ha.

On comparing the values for the difference of main plot means at the same level of sub plots, it was found that, at the level F_0(0 kg P_2O_5 / ha), $F_0P_1(90)$ gave the maximum value. $F_0P_4(90)$, $F_0P_3(90)$, $F_0P_4(70)$, $F_0P_1(70)$, $F_0P_3(70)$ and $F_0P_2(90)$ did not show critical difference with each other. The control (F_0P_0) gave the minimum value but its effect was equal to that of $F_0P_2(90)$ and $F_0P_2(70)$. At the 30 kg P_2O_5 / ha level, equal effect was noted for the treatments $F_{30}P_4(70)$, $F_{30}P_1(70)$ and $F_{30}P_1(90)$. The control, $F_{30}P_0$, was found better than the treatment $F_{30}P_3(90)$ but its effect was not critically different from the effect of $F_{30}P_2(90)$ and $F_{30}P_3(90)$.

Table 18. Effect of foliar and soil application of phosphorus on grain number per ear in NP 13 barley

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	Sub plot (soil dressing) 30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	36.00	38.40	37.20
2. P_1 (70)	40.93	47.86	44.40
3. P_2 (70)	37.66	43.93	40.80
4. P_3 (70)	40.13	40.40	40.26
5. P_4 (70)	40.93	47.93	44.43
6. P_1 (90)	44.33	46.20	45.26
7. P_2 (90)	38.26	39.86	39.06
8. P_3 (90)	41.20	37.40	39.30
9. P_4 (90)	41.93	43.40	42.66
Mean	40.15	42.82	

C.D. for main plot treatment at 5% = 2.03

C.D. for sub plot treatment at 5% = 0.84

C.D. for the difference of main plot means at the same level of sub plot = 2.70

C.D. for the difference of sub plot means at the same level of main plot = 2.52

Regarding the differences of sub plot means at the same level of main plots, better results were obtained by the spray treatments at 30 kg P_2O_5 / ha as compared with those at 0 kg P_2O_5 / ha except the treatment $F_0P_3(90)$ which produced significantly more grains per ear than its counterpart $F_{30}P_3(90)$. The effect of the spray treatments at F_0(0 kg P_2O_5 / ha), i.e. F_0P_0, $F_0P_3(70)$, $F_0P_1(90)$, $F_0P_3(90)$ and $F_0P_4(90)$ was superior to their respective effect at the F_{30}(30 kg P_2O_5 / ha) level. The rest of the treatments at one level differed critically in their effect from that of their respective counterparts at the other basal level.

4.1.2.6. Weight of 1,000 grain. The effect of foliar and soil fertiliser phosphorus on the weight of 1,000 grain was found to be significant. The difference of the values of the main plots at the same level of sub plots and vice-versa was also noted to be significant. The result is briefly discussed below and given in Table 19.

Regarding the effect of foliar spray, maximum grain weight was obtained by the treatment $P_1(90)$ (3.3 per cent more than control). The next best value was found for $P_1(70)$. The treatments $P_4(70)$ and $P_3(70)$ differed critically from each other as well as from the rest of the treatments. Equal effect was noted in treatments $P_3(90)$, $P_2(70)$ and $P_4(90)$ as also in $P_4(90)$ and $P_2(90)$. P_0, the water sprayed control, gave the minimum value.

Basal dose of phosphorus at the rate of 30 kg P_2O_5 / ha

Table 19. Effect of foliar and soil application of phosphorus on weight of 1,000 grain in NP 13 barley (g)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	Sub plot (soil dressing) 30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	36.305	36.983	36.644
2. P_1 (70)	37.662	37.585	37.623
3. P_2 (70)	36.602	37.306	36.954
4. P_3 (70)	37.311	37.202	37.257
5. P_4 (70)	37.173	37.672	37.423
6. P_1 (90)	37.637	38.058	37.847
7. P_2 (90)	37.176	36.504	36.840
8. P_3 (90)	36.638	37.324	36.981
9. P_4 (90)	36.441	37.444	36.942
Mean	36.994	37.342	

C.D. for main plot treatment at 5% = 0.107

C.D. for sub plot treatment at 5% = 0.047

C.D. for the difference of main plot means at the same level of sub plot = 0.147

C.D. for the difference of sub plot means at the same level of main plot = 0.141

gave significantly but slightly (0.9 per cent) higher value than 0 kg P_2O_5 / ha. Both the doses differed critically from each other in their effect.

When the values for the difference of spray treatment means at the same level of soil treatments were taken into consideration, the treatments $F_0P_1(70)$ and $F_0P_1(90)$, at the 0 kg P_2O_5 / ha level of basal dressing, showed equal effect. On the other hand, $F_0P_3(70)$, $F_0P_2(90)$ and $F_0P_4(70)$ also did not differ critically from each other. $F_0P_3(90)$ and $F_0P_2(70)$ were similar in their effect. The performance of the water-sprayed control was noted to be poorest for test weight but its effect was equal to that of treatment $F_0P_4(90)$. At 30 kg P_2O_5 / ha level, $F_{30}P_1(90)$ gave the maximum value. Next in effect were treatments $F_{30}P_4(70)$ and $F_{30}P_1(70)$ which gave equal values. It may, however, be noted that the control, i.e. $F_{30}P_0$ was slightly superior than the poorest treatment $F_{30}P_2(90)$ which gave significantly lowest value.

When the differences of sub plot means (soil treatments) at the same level of main plots (spray treatments) were taken into account, it was noted that the treatments $F_0P_1(90)$, $F_0P_3(70)$ and $F_0P_2(90)$ gave higher values than their respective counterparts $F_{30}P_1(90)$, $F_{30}P_3(70)$ and $F_{30}P_2(90)$, whereas, the majority of the treatments showed a better effect at F_{30}(30 kg P_2O_5 / ha) than at F_0(0 kg P_2O_5 / ha). All the spray treatment pairs of combination i.e. the same treatment at both the soil fertiliser levels, differed critically from each other, except $F_0P_1(70)$ and $F_0P_3(70)$ which showed no critical difference from their respective counterparts $F_{30}P_1(70)$ and $F_{30}P_3(70)$.

4.1.2.7. Total yield per hectare. Total yield of plants was significantly affected by foliar as well as soil application of phosphorus. However, the interaction between foliar and soil application was noted to be non-significant (Table 20).

Among spray treatments, $P_4(90)$, $P_3(70)$, $P_3(90)$, $P_4(70)$ and $P_2(90)$ did not show critical difference in their effect. On the other hand, all the remaining treatments, except $P_4(90)$ were similar in their effect. The maximum increase in yield over the minimum value was 21.0 per cent.

A significant increase in total yield was recorded with 30 kg basal P_2O_5 / ha in comparison with 0 kg P_2O_5 / ha. The increase over the control was about 12.0 per cent.

4.1.2.8. Grain yield per hectare. Total grain yield was significantly affected both by foliar application as well as by basal dressing of phosphorus. However, the difference between two combination means was not significant (Table 21).

The data for spray treatments indicated that $P_4(90)$, $P_4(70)$ and $P_3(70)$ were equal in effect. The rest of the

Table 20. Effect of foliar and soil application of phosphorus on total yield in NP 13 barley (q/ha)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (F_0)	30 kg P_2O_5/ha (F_{30})	Mean
	Mean of three replicates		
1. P_0	51.110	60.677	55.893
2. P_1(70)	50.308	57.035	53.671
3. P_2(70)	52.961	57.036	54.998
4. P_3(70)	57.332	66.382	61.857
5. P_4(70)	58.242	63.270	60.756
6. P_1(90)	54.529	56.912	55.721
7. P_2(90)	56.392	60.727	58.559
8. P_3(90)	58.024	63.702	60.863
9. P_4(90)	60.937	69.123	65.030
Mean	55.537	61.651	

C.D. for main plot treatment at 5% = 6.792

C.D. for sub plot treatment at 5% = 2.616

C.D. for the difference of main plot means at the same level of sub plot = 8.771

C.D. for the difference of sub plot means at the same level of main plot = 7.849

Table 21. Effect of foliar and soil application of phosphorus on grain yield in NP 13 barley (q/ha)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	23.456	25.987	24.721
2. P_1 (70)	22.962	26.666	24.814
3. P_2 (70)	24.814	26.913	25.863
4. P_3 (70)	23.505	31.789	27.647
5. P_4 (70)	27.098	28.765	27.907
6. P_1 (90)	24.286	25.061	24.672
7. P_2 (90)	25.678	24.135	24.907
8. P_3 (90)	25.678	26.295	25.987
9. P_4 (90)	27.530	31.851	29.690
Mean	25.000	27.496	

C.D. for main plot treatment at 5% = 3.029

C.D. for sub plot treatment at 5% = 1.887

C.D. for the difference of main plot means at the same level of sub plot = 5.021

C.D. for the difference of sub plot means at the same level of main plot = 5.663

treatments, including $P_4(70)$ and $P_3(70)$, on the other hand, gave similar yield of grains. The increase of yield by $P_4(90)$ over the minimum value recorded by $P_1(90)$ was approximately 21.0 per cent.

The application of 30 kg P_2O_5 / ha solid fertiliser gave about 10.0 per cent increase in yield of grain over 0 kg P_2O_5 / ha, the control, both the applications being critically different from each other in their effect on grain yield.

4.1.2.9. Straw yield per hectare. The effect on straw production was found to be significant only as a result of basal dressing with phosphorus (Table 22).

Basal application of phosphorus at the rate of 30 kg P_2O_5 / ha gave about 10.0 per cent higher yield of straw as compared with 0 kg P_2O_5 / ha.

4.1.3. Nutrient content:

The nutrients studied included total nitrogen, phosphorus and potassium in laminae of fully expanded, mature leaves. Like growth characteristics, the NPK content, expressed as percentage of dry weight, was determined at heading and milky grain stage. The data are presented in Tables 23 to 28 and summarised below:

4.1.3.1. Nitrogen. The nitrogen concentration of leaves was significantly affected by foliar as well as basal phosphorus at

Table 22. Effect of foliar and soil application of phosphorus on straw yield in RP 13 barley (q/ha)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	27.654	35.431	31.542
2. P_1 (70)	27.345	30.369	28.857
3. P_2 (70)	28.456	30.123	29.289
4. P_3 (70)	33.826	31.259	32.542
5. P_4 (70)	31.110	34.505	32.808
6. P_1 (90)	30.346	31.851	31.048
7. P_2 (90)	30.713	36.592	33.652
8. P_3 (90)	32.345	37.407	34.876
9. P_4 (90)	33.740	36.604	35.172
Mean	30.604	33.793	

C.D. for main plot treatment at 5% = 5.232

C.D. for sub plot treatment at 5% = 1.692

C.D. for difference of main plot means at the same level of sub plot = 6.348

C.D. for the difference of sub plot means at the same level of main plot = 5.083

both the stages. The interaction between foliar and soil application was also noted to be significant. The results are shown in Table 23 and 24.

Spray treatments at heading stage showed that maximum concentration of nitrogen in leaves (26.6 per cent more than P_0, the control) was shown by the treatment $P_2(70)$. $P_1(70)$ and $P_4(70)$ did not differ critically in their effect. The remaining treatments $P_3(70)$ and P_0 showed significant difference, P_0 being poorest in effect.

The value for the percentage of nitrogen for 30 kg P_2O_5/ha applied to the soil was lower by 4.1 per cent than for 0 kg P_2O_5 / ha. The difference between them was critically significant.

When the values for the differences among the five main plot means at the same level of two sub plots were considered, it was noted that, at F_0(0 kg P_2O_5/ ha) basal level, the maximum value was recorded in the treatment $F_0P_2(70)$ followed by $F_0P_4(70)$, $F_0P_3(70)$, $F_0P_1(70)$ and F_0P_0, each treatment being critically different from the other. At 30 kg P_2O_5/ha, the treatments $F_{30}P_2(70)$ and $F_{30}P_1(70)$ showed equal effect. The effect of $F_{30}P_4(70)$ and $F_{30}P_3(70)$ did not differ critically. The minimum value was recorded in $F_{30}P_0$.

The difference of two sub plot means at the same level of five main plots showed that the treatments F_0P_0 and $F_0P_1(70)$

Table 23. Effect of foliar and soil application of phosphorus at heading stage on leaf nitrogen concentration in RP 13 barley (% dry wt)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	3.22	3.61	3.41
2. P_1 (70)	3.96	4.09	4.02
3. P_2 (70)	4.51	4.14	4.32
4. P_3 (70)	4.14	3.71	3.92
5. P_4 (70)	4.27	3.77	4.02
Mean	4.02	3.86	

C.D. for main plot treatment at 5% = 0.05

C.D. for sub plot treatment at 5% = 0.04

C.D. for the difference of the main plot means at the same level of sub plot = 0.09

C.D. for the difference of the sub plot means at the same level of main plot = 0.10

Table 24. Effect of foliar and soil application of phosphorus at milky grain stage on leaf nitrogen concentration in NP 13 barley (% dry weight)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	2.812	2.287	2.549
2. P_1 (70)	3.475	2.812	3.143
3. P_2 (70)	3.233	2.750	2.991
4. P_3 (70)	3.113	2.708	2.910
5. P_4 (70)	2.958	2.708	2.833
6. P_1 (90)	2.841	2.341	2.591
7. P_2 (90)	3.133	2.375	2.754
8. P_3 (90)	3.704	2.499	3.101
9. P_4 (90)	3.137	2.866	3.002
Mean	3.098	2.652	

C.D. for main plot treatment at 5% = 0.086

C.D. for sub plot treatment at 5% = 0.039

C.D. for the difference of main plot means at the same level of sub plot = 0.120

C.D. for the difference of sub plot means at the same level of main plot = 0.119

gave a lower value as compared with their respective counterparts $F_{30}P_0$ and $F_{30}P_1(70)$. The remaining treatments $F_0P_2(70)$, $F_0P_3(70)$ and $F_0P_4(70)$ increased the foliar nitrogen concentration over their respective counterparts.

At milky grain stage, the spray treatments $P_1(70)$ and $P_3(90)$ gave similar high results (23.3 per cent higher than P_0). Next in order were treatments $P_4(90)$ and $P_2(70)$ and their effects were also not critically different from each other. Treatments $P_1(90)$ and P_0, the control sprayed with water only, gave equal minimum value.

0 kg P_2O_5 / ha, as basal dressing, gave 6.0 per cent higher value for the nitrogen content of leaves in comparison with 30 kg P_2O_5 / ha level of phosphorus.

All spray treatments (main plot) at 0 kg P_2O_5 / ha gave significantly higher values as compared with the treatment F_0P_0, the control, sprayed with water only. The maximum value was recorded in the treatment $F_0P_3(90)$. At 30 kg P_2O_5 / ha, $F_{30}P_4(90)$ was most effective for the concentration of nitrogen in leaves followed by $F_{30}P_1(70)$ and $F_{30}P_2(70)$, differing critically in its effect from that of the others. $F_{30}P_3(70)$ and $F_{30}P_4(70)$ were, also equal in their effect. $F_{30}P_0$, the control gave the minimum value.

When the values for the difference of sub plot means at the same level of main plots were taken into consideration, it was found that all the treatments at 0 kg P_2O_5 / ha gave significantly higher values than their respective counterparts at 30 kg P_2O_5 / ha.

4.1.3.2. Phosphorus. The phosphorus concentration in leaves was significantly affected by spray as well as basal dressing of phosphorus at both the stages. The interaction effect between spray and soil application was, however, found to be non-significant at heading stage. The data are presented in Tables 25 and 26.

At heading stage, among spray treatments, a gradual increase in concentration of leaf phosphorus was noted from the water-sprayed control, P_0, to the highest dose applied at 70 days i.e. $P_4(70)$, which showed 51.4 per cent increase over P_0. The treatments $P_3(70)$ and $P_2(70)$, which had equal effect, came next in order.

The value for phosphorus concentration in the leaves was 6.6 per cent lower for 0 kg P_2O_5 / ha than for 30 kg P_2O_5/ ha applied to the soil at the time of sowing.

At milky grain stage it was noted that the spray treatment $P_4(90)$ had pronounced effect on the phosphorus

Table 25. Effect of foliar and soil application of phosphorus at heading stage on leaf phosphorus concentration in HP 13 barley (% dry weight)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	0.298	0.320	0.309
2. P_1 (70)	0.390	0.430	0.410
3. P_2 (70)	0.443	0.453	0.448
4. P_3 (70)	0.435	0.472	0.453
5. P_4 (70)	0.458	0.479	0.468
Mean	0.404	0.431	

C.D. for main plot treatment at 5% = 0.012

C.D. for sub plot treatment at 5% = 0.007

C.D. for the difference of main plot means at the same level of sub plot = 0.017

C.D. for the difference of sub plot means at the same level of main plot = 0.017

Table 26. Effect of foliar and soil application of phosphorus at milky grain stage on leaf phosphorus concentration in NP 13 barley (% dry weight)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	0.282	0.302	0.292
2. P_1 (70)	0.263	0.319	0.291
3. P_2 (70)	0.266	0.322	0.294
4. P_3 (70)	0.357	0.321	0.339
5. P_4 (70)	0.336	0.368	0.352
6. P_1 (90)	0.304	0.286	0.295
7. P_2 (90)	0.312	0.329	0.320
8. P_3 (90)	0.343	0.348	0.345
9. P_4 (90)	0.354	0.368	0.361
Mean	0.313	0.329	

C.D. for main plot treatment at 5% = 0.003

C.D. for sub plot treatment at 5% = 0.001

C.D. for the difference of main plot means at the same level of sub plot = 0.005

C.D. for the difference of sub plot means at the same level of main plot = 0.005

concentration in leaves in comparison with the control, being 24.0 per cent higher. The treatment next in effect was P_4(70), whereas treatments P_0 and P_1(70) were found to be the most inferior in this regard. These last two did not differ critically from each other in their effect.

A significant increase of 5.1 per cent in leaf phosphorus concentration was noted by the application of 30 kg P_2O_5 / ha over the control (no fertiliser phosphorus applied to the soil).

Regarding the differences of main plot means at the same level of sub plots, it was noted that at the F_0 level, the treatments F_0P_3(70) and F_0P_4(90) gave the maximum but equal values. The treatments that followed in order were F_0P_3(90) and F_0P_4(70) which differed critically from each other. The poorest effect was noted for the treatments F_0P_2(70) and F_0P_1(70). At 30 kg P_2O_5 / ha level, the best combinations, $F_{30}P_4$(90) and $F_{30}P_4$(70), were not critically different in their effect. The minimum leaf phosphorus concentration was noted for the treatment $F_{30}P_1$(90). The control, $F_{30}P_0$, was slightly superior to $F_{30}P_1$(90).

When the comparison of two treatment combination means of sub plots at the same level of main plots was considered, it was noted that all the treatments at 30 kg P_2O_5 / ha level gave significantly higher values than those at 0 kg P_2O_5 / ha, except F_0P_3(70) which was significantly superior than its counterpart $F_{30}P_3$(70).

4.1.3.3. Potassium. Significant effect was noted by spray as well as basal dressing of phosphorus on potassium concentration in leaves at heading stage only. The interaction between spray and soil application of phosphorus was noted to be significant at heading stage only. However, the effect of foliar spray, soil fertilisation and interaction was found to be non-significant at milky grain stage. The data are given in Tables 27 and 28.

Among spray treatments, at heading stage, the treatments P_3(70) and P_0 showed equal effect. On the other hand P_0 and P_4(70) were also equal in their effect, so was the effect of of P_4(70) and P_2(70). The minimum value was recorded for the treatment P_1(70).

Regarding basal dressing, it may be noted that 30 kg P_2O_5/ ha was found to be better than 0 kg P_2O_5/ ha for the concentration of potassium in leaves.

When the differences of main plot means at the same level of sub plots were considered, it was found that, at 0 kg P_2O_5 / ha, the control (F_0P_0) gave the maximum value as compared with the rest of the treatments which were equal in their effect.

Table 27. Effect of foliar and soil application of phosphorus at heading stage on leaf potassium concentration in NP 13 barley (% dry weight)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	1.38	1.10	1.24
2. P_1 (70)	0.70	0.85	0.77
3. P_2 (70)	0.86	1.06	0.96
4. P_3 (70)	0.81	2.15	1.48
5. P_4 (70)	1.00	1.08	1.04
Mean	0.95	1.25	

C.D. for main plot treatments at 5% = 0.27

C.D. for sub plot treatments at 5% = 0.14

C.D. for the difference of main plot means at the same level of sub plot = 0.36

C.D. for the difference of sub plot means at the same level of main plot = 0.32

Table 28. Effect of foliar and soil application of phosphorus at milky grain stage on leaf potassium concentration in NP 13 barley (% dry weight)

Main plot (Spray treatments)	Sub plot (soil dressing) 0 kg P_2O_5/ha (P_0)	30 kg P_2O_5/ha (P_{30})	Mean
	Mean of three replicates		
1. P_0	0.71	0.76	0.74
2. P_1 (70)	0.51	0.65	0.58
3. P_2 (70)	0.66	0.50	0.58
4. P_3 (70)	0.68	0.78	0.73
5. P_4 (70)	0.55	0.71	0.63
6. P_1 (90)	0.53	0.63	0.58
7. P_2 (90)	0.75	0.98	0.86
8. P_3 (90)	0.76	0.85	0.80
9. P_4 (90)	0.83	0.50	0.66
Mean	0.66	0.70	

C.D. for main plot treatment at 5% = N.S.

C.D. for sub plot treatment at 5% = N.S.

C.D. for the difference of main plot means at the same level of sub plot = N.S.

C.D. for the difference of sub plot means at the same level of main plot = N.S.

N.S. Non-significant.

whereas at 30 kg P_2O_5 / ha, the treatment $F_{30}P_3(70)$ gave significantly higher value, the rest of the treatments, $F_{30}P_0$, $F_{30}P_4(70)$, $F_{30}P_2(70)$ and $F_{30}P_4(70)$ did not show critical difference from each other in their response.

When two combination means of subplots at the same level of main plots were compared, it was found that only the treatment $F_0P_3(70)$ differed critically in its effect from its counterpart $F_{30}P_3(70)$. The rest of the combination pairs did not differ critically from each other.

4.2. Experiment 2.

Results pertaining to the effect of different doses of phosphorus (with and without "Dimecron-100") on the growth, yield and NPK content of NP 13 barley are given below and are summarised in Tables 29 to 31.

4.2.1. Growth characteristics:

Two stages, namely, heading stage and milky grain stage, were chosen for recording the data about different growth characteristics, which are described below (Table 29).

4.2.1.1. Tiller number. At heading stage, tiller number per plant was affected significantly by the treatments. Of these, P_3D, showing equal effect with treatment P_0D, 2 x P_1D, P_2D,

Table 29. Effect of different doses of leaf-applied phosphorus (with or without "Dimecron-100") on growth characteristics of NP13 barley

Stage	Spray treatments										C.D. at 5%
	P_0D_0	P_0D	P_1D_0	P_2D_0	P_3D_0	P_1D	P_2D	P_3D	$2xP_1D_0$	$2xP_1D$	
					Mean of three replicates						
					Tiller number per plant						
Heading	13.33	19.66	13.93	16.46	16.66	16.60	17.00	20.20	14.46	17.53	3.73
Milky grain	20.20	32.73	20.46	23.93	25.73	23.26	26.40	34.80	25.33	28.99	6.25
					Fresh weight per five plants (g)						
Heading	544.00	818.03	686.93	714.09	730.33	732.25	780.93	960.13	649.13	765.16	Non-significant
Milky grain	954.00	1730.00	1020.00	1070.00	1280.00	1110.00	1510.00	1730.00	1270.00	1310.00	319.00
					Dry weight per five plants (g)						
Heading	105.66	157.33	122.19	128.60	140.33	133.96	144.63	166.10	122.80	130.53	Non-significant
Milky grain	284.20	375.83	287.96	307.56	333.36	315.50	353.06	439.16	322.93	381.46	79.9

P_3D_0 and P_1D, produced significantly more tillers per plant than the remaining treatments, P_2D_0, $2 \times P_1D_0$, P_1D_0 and P_0D_0 (control) which among themselves showed equal effect.

At milky grain stage also, the effect of treatments on tiller number per plant was significant. All the treatments gave higher values than the control. Except for P_1D_0, all values differed critically from that of the control. Treatment P_3D, which gave the highest value (72.2 per cent more than control), did not show critical difference from P_0D and $2 \times P_1D$. On the other hand, treatment $2 \times P_1D$ had equal effect with the rest of the treatments.

4.2.1.2. Fresh weight. Fresh weight of shoots at the heading stage was non-significant, but the treatment P_3D gave the maximum and the control (P_0D_0), the minimum value. The treatments P_0D and $2 \times P_1D$ were also found rather effective.

However, it may be noted that the effect of different treatments on fresh weight at the milky grain stage was found to be significant. All the treatments produced significantly higher fresh weight over the untreated control. The maximum increase (81.3 per cent over the control, P_0D_0) in fresh weight was noted in treatment P_3D but its effect did not differ critically from that of treatments P_0D and P_2D. The remaining treatments $2 \times P_1D$, P_3D_0, $2 \times P_1D_0$, P_1D, P_2D and P_1D_0 produced equal effect amongst themselves.

4.2.1.3. Dry weight. Dry weight of shoots was not significantly affected at heading stage by the different spray treatments but the trend was almost similar to that of the fresh weight at the same stage.

On the other hand, the effect of treatments on this characteristic was significant at the milky grain stage, the maximum increase of 51 per cent over P_0D_0 being noted in treatment P_3D. This beneficial effect was, however, equalled by treatments $2 \times P_1D$ and P_0D. These three treatments differed critically in their effect from all others, including the control. All treatments gave higher values than the control.

4.2.2. Yield characteristics

Most of the yield characteristics studied were found to be affected significantly by the treatments. The details for each are given below (Table 30).

4.2.2.1. Ear number per plant. Application of different doses of phosphorus in spray with and without "Dimecron-100" gave significantly higher values for ear number per plant compared to the spray of de-ionised water. The treatments $2 \times P_1D$, P_3D, P_0D, P_2D and $2 \times P_1D_0$ showing 34.3 per cent increase over the control, proved better than the remaining

Table 30. Effect of different doses of leaf-applied phosphorus (with or without 'Dimecron-100') on yield characteristics of NP13 barley

Spray treatments										C.D. at 5%
P_0D_0	P_0D	P_1D_0	P_2D_0	P_3D_0	P_1D	P_2D	P_3D	$2 \times P_1D_0$	$2 \times P_1D$	
			Mean of three replicates							
			Ear number per plant							
18.06	23.40	20.08	20.39	20.40	19.33	21.76	23.46	21.66	24.66	2.70
			Weight of ears per five plants (g)							
32.50	44.09	33.83	34.86	37.80	34.90	37.86	45.09	39.13	45.23	5.36
			Length per ear (cm)							
14.89	16.33	15.16	16.03	16.26	16.16	16.20	16.26	15.96	16.40	Non-significant
			Spikelet number per ear							
17.13	19.13	18.53	20.06	19.86	19.00	20.06	19.86	19.26	20.06	Non-significant
			Number of grains per ear							
46.13	50.66	50.40	52.86	53.26	53.19	53.59	54.26	46.59	54.26	Non-significant
			1,000 grain weight (g)							
31.79	32.60	32.13	33.59	33.90	32.89	33.71	34.03	33.53	34.96	0.911
			Yield of plants (q/ha)							
94.933	102.333	96.934	103.931	108.742	105.898	106.173	109.481	107.742	113.078	0.0063
			Yield of grains (q/ha)							
38.143	41.223	40.560	42.336	46.400	41.443	43.356	47.110	42.890	48.426	0.1485
			Yield of straw (q/ha)							
52.818	55.931	55.158	60.851	62.817	62.191	64.017	64.307	62.962	65.788	0.0059

treatments but did not differ critically from each other. It may be added that the last two of these treatments were themselves not critically different in their effect from the rest of the treatments i.e., P_3D_0, P_2D_0, P_1D_0 and P_1D.

4.2.2.2. Weight of ears. Weight of ears per plant was significantly affected by the treatments. Minimum value was obtained for the control not receiving phosphorus or "Dimecron-100" in spray. However, this did not differ critically from the values for the treatments P_2D, P_3D, P_1D, P_2D_0 and P_1D_0. Significantly higher values were noted for the remaining treatments, namely, $2 \times P_1D$, P_3D, P_0D and $2 \times P_1D_0$, being 39.1 per cent higher than the control, P_0D_0. Among these, the first three showed equal effect. Similarly, the last two also did not differ critically from each other.

4.2.2.3. Length per ear. The effect of various treatments on ear length was non-significant. It may, however, be noted that the longest ears were formed in plants given the treatment $2 \times P_1D$ whereas the control, P_0D_0, gave the poorest response.

4.2.2.4. Spikelet number per ear. The number of spikelets per ear was not affected significantly by the treatments, but it was noted that treatments $2 \times P_1D$, P_2D and P_3D_0 gave better results than the others. The ears of the control, P_0D_0, produced the lowest number of spikelets.

4.2.2.5. <u>Number of grains per ear.</u> The effect of various treatments on the number of grains per ear was also non-significant. It is worth noting, however, that treatments $2 \times P_1D$ and P_3D produced more grains per ear than the remaining treatments, with the control, P_0D_0, proving the most inferior in this respect.

4.2.2.6. <u>1,000 grain weight.</u> The effect of different treatments on 1,000 grain weight was significant. The value for the treatment $2 \times P_1D$ was maximum, being 9.9 per cent higher than P_0D_0, followed by the value for P_3D. These two higher values differed critically from each other. Critical difference was not recorded in the values for P_3D_0, P_2D, P_2D_0 and $2 \times P_1D_0$ but the values were higher than those for P_1D, P_0D and P_1D_0 which themselves were found to have equal effect. The control, P_0D_0, which produced the lowest 1,000 grain weight, differed critically from all other treatments in this regard.

4.2.2.7. <u>Total weight of plants.</u> The total yield of plants per hectare was significantly affected by the different spray treatments. Maximum value was recorded for the treatment $2 \times P_1D$, showing approximately 19.0 per cent increase over the control (P_0D_0) which possessed the minimum weight. The effect of all the treatments differed critically from each other.

4.2.2.8. Total weight of grains. The effect of different spray treatments on the total weight of grains per hectare was significant. The value for the treatment 2 x P_1D was maximum, showing about 26.0 per cent increase over the control. Also, critical differences among all other treatments were recorded. The minimum grain weight was found for the treatment P_0D_0, the control.

4.2.2.9. Total weight of straw. The weight of straw of plants per hectare was found to be significantly affected by the different spray treatments. The treatment 2 x P_1D was found to be the best and produced the maximum straw weight giving approximately 25.0 per cent increase over the control. The minimum value was recorded for the control (P_0D_0). The rest of the treatments showed critical difference with each other.

4.2.3. Nutrient content:

Nitrogen, phosphorus and potassium were analysed in leaves of NP 13 barley. The effect of different spray treatments on their contents was recorded and data are given in Table 31.

4.2.3.1. Nitrogen. The nitrogen content in leaves was significantly affected by different spray treatments at both the stages of growth, namely, heading stage and milky grain stage.

Table 31. Effect of different doses of leaf-applied phosphorus (with or without 'Dimecron-100') on leaf N P K concentration of NP 13 barley

Stage	Spray treatments										C.D. at 5%
	P_0D_0	P_0D	P_1D_0	P_2D_0	P_3D_0	P_1D	P_2D	P_3D	$2xP_1D_0$	$2xP_1D$	
					Mean of three replicates						
					Nitrogen (% dry weight)						
Heading	2.1633	2.3933	2.6066	3.1000	3.8930	3.3500	3.2666	3.3533	3.1400	2.6832	0.2970
Milky grain	2.9600	3.3100	3.3430	3.3533	2.5166	2.6066	3.0000	2.6966	2.6833	3.1833	0.2970
					Phosphorus (% dry weight)						
Heading	0.3333	0.3400	0.3600	0.3900	0.4166	0.3766	0.3866	0.4166	0.4133	0.4166	0.0059
Milky grain	0.2166	0.2833	0.2900	0.2766	0.3400	0.2233	0.2300	0.2866	0.2366	0.3233	0.0089
					Potassium (% dry weight)						
Heading	1.150	1.100	0.850	0.883	0.700	0.700	0.750	0.733	0.700	0.850	0.1336
Milky grain	0.633	0.650	0.550	0.583	0.600	0.683	0.550	0.633	0.600	0.700	Non-significant

At heading stage, the treatment P_3D_0 gave the maximum value 79.9 per cent more than P_0D_0, the control. Equal effect was noted in treatments P_3D, P_1D, P_2D, $2 \times P_1D_0$ and P_2D_0. So also were the values for treatments $2 \times P_1D$, P_1D_0 and P_0D. The latter treatment, P_0D, did not show critical difference in effect from P_0D_0, the water-sprayed control.

At milky grain stage, P_2D_0, P_1D_0, P_0D and $2 \times P_1D$ gave 33.2 per cent higher values than the least effective treatment, P_3D_0 and showed equal effect among themselves. Similarly, P_2D, P_0D_0, P_3D and $2 \times P_1D$ were equal in their effect. The latter two treatments and the remaining treatments i.e. P_1D and P_3D_0, did not differ critically from each other.

4.2.3.2. <u>Phosphorus</u>. Concentration of phosphorus in leaves was significantly affected by different spray treatments at both the stages of growth.

At heading stage, the (equal) effect of treatments P_3D_0, $2 \times P_1D$, P_3D and $2 \times P_1D_0$ was 24.9 per cent better than P_0D_0. A similar equal effect was also noted in treatments P_2D_0 and P_2D. The rest of the treatments differed critically from each other.

At milky grain stage, significant maximum value (56.9 per cent higher than for P_0D_0) was recorded for the treatment P_3D_0. Next was the value for treatment $2 \times P_1D$, differing critically from all others. The treatments P_1D_0, P_3D and P_0D were found to be equal in their effect. The effect of P_0D was equal to the treatment P_2D_0. Similarly, $2 \times P_1D_0$ and P_2D did not differ critically from each other and the latter treatment showed equal effect to that of treatment P_1D. On the other hand, no critical difference was noted in the treatments P_1D and P_0D_0, the water-sprayed control.

4.2.3.3. Potassium. The effect of various spray treatments on leaf potassium content was recorded to be significant, at heading stage. However, at milky grain stage, the effect was non-significant.

At the earlier stage, the treatments P_0D_0 and P_0D gave the maximum value but showed equal effect. The treatments P_2D_0, P_1D_0 and $2 \times P_1D$ exhibited lower (equal) effect. The remaining treatments did not differ critically from each other, indicating their equal effect.

4.3. Experiment 3.

The effect of different doses of phosphorus, with and without "Dimecron-100" on the growth and yield characteristics, and seed quality, and leaf NPK content of Laha-101, grown under field conditions, are given below (Table 32, 33 and 34).

4.3.1. Growth characteristics

Data regarding growth characteristics were recorded at two selected stages of growth, namely, flowering and fruiting stage. These are presented in Table 32 and the salient points, given below.

4.3.1.1. Shoot length. Vertical growth of plants was affected significantly by the treatments at the flowering stage. The maximum value was obtained with treatment P_3D, being 21.4 per cent higher than that for the control, treated with de-ionised water only. But it did not differ critically from those for $2 \times P_1D$, P_3D_0, P_1D and P_2D. The lowest value was obtained in the control (P_0D_0) but its effect was equal to that of P_1D, P_2D, P_2D_0, $2 \times P_1D_0$, P_0D and P_1D_0.

The effect of different treatments on shoot length per plant was found significant at fruiting stage also. Treatments $2 \times P_1D$, P_3D and P_2D, which showed equal effect, gave significantly higher values than those for other treatments, being 15.7 per cent higher than the untreated control (P_0D_0). The effect of the rest of treatments did not show critical differences among themselves.

4.3.1.2. Fresh weight. The effect of leaf-applied phosphorus and "Dimecron-100" on fresh weight was significant. All the

Table 32. Effect of different doses of leaf-applied phosphorus (with or without 'Dimecron-100') on growth characteristics of Laha-101

Stage	Spray treatments P_0D_0	P_0D	P_1D_0	P_2D_0	P_3D_0	P_1D	P_2D	P_3D	$2xP_1D_0$	$2xP_1D$	C. D. at 5%
					Mean of three replicates						
					Shoot length per plant (cm)						
Flowering	97.2	102.0	100.0	105.0	109.0	108.0	108.0	118.0	105.0	112.0	11.0
Fruiting	165.0	172.0	166.0	172.0	170.0	170.0	185.0	188.0	174.0	191.0	11.9
					Fresh weight per five plants (g)						
Flowering	294.0	385.0	380.0	485.0	497.0	478.0	585.0	595.0	582.0	702.0	166.0
Fruiting	504.0	645.0	610.0	679.0	744.0	705.0	1190.0	1290.0	1230.0	1230.0	159.0
					Dry weight per five plants (g)						
Flowering	32.8	54.1	37.9	48.4	51.2	50.5	58.5	66.5	54.2	73.8	20.8
Fruiting	135.0	171.0	158.0	165.0	210.0	193.0	335.0	354.0	353.0	378.0	50.2

treatments, except P_1D_0 and P_0D, produced significant higher fresh weight than the control, sprayed with de-ionised water. The maximum value was recorded for $2 \times P_1D$, being 138.6 per cent more than for P_0D_0 and showing equal effect with P_3D, P_2D and $2 \times P_1D_0$. The values differed critically from the values for the rest of the treatments. Regarding the other treatments, values for P_3D, P_2D, $2 \times P_1D_0$, P_3D_0, P_2D_0 and P_1D did not differ critically from each other. Similarly, the treatments P_3D_0, P_2D_0, P_1D, P_0D and P_1D_0 also showed equal effect on the fresh weight of plants.

Significant effect of treatments on fresh weight was noted at fruiting stage also. The treatments P_3D, $2 \times P_1D$, $2 \times P_1D_0$ and P_2D, showing significantly higher values over the control, had an equal effect on the fresh weight and the values critically differed from those of the treatments P_3D_0, P_1D and P_2D_0. These latter treatments did not differ critically from each other in their effect. Values for P_0D and P_1D_0 did not differ significantly from that of untreated control, P_0D_0. It may be noted that the maximum fresh weight was 151.9 per cent more than that of P_0D_0 and was noted in treatment P_3D.

4.3.1.3. Dry weight. The effect of different treatments on the dry matter of shoots was significant. The maximum value (125 per cent more than P_0D_0) was recorded for the treatment $2 \times P_1D$, but the effect was equal to that of treatments P_3D,

P_2D, 2 x P_1D_0 and P_0D. These latter four treatments also showed an effect equal to that of treatments P_3D_0, P_1D and P_2D_0 but differed critically from P_1D_0 and P_0D_0. Except for treatments 2 x P_1D, P_3D and P_0D_0, the control, all other treatments were found to be equal in their effect. Similarly, the treatments P_3D_0, P_1D, P_2D_0 and P_1D_0 did not show critical difference with the control, P_0D_0.

At fruiting stage also, the effect of treatments on dry weight was found significant, the best, 2 x P_1D, giving 160 per cent higher value over the control, P_0D_0. The treatments 2 x P_1D, P_3D, 2 x P_1D_0 and P_2D produced equal effect and differed critically from P_3D, P_1D, P_0D and P_2D_0, which, in their turn, were found to have equal effect on the dry weight of shoots at this stage.

4.3.2. <u>Yield characteristics</u>:

The effect of various spray treatments on yield characteristics, including the total yield of seed, oil and protein per hectare, were noted and are summarised in Table 33.

4.3.2.1. <u>Seed yield per hectare</u>. The effect of various spray doses on seed yield was found to be significant. The effect of treatment 2 x P_1D was best, showing 63.3 per cent increase over the water-sprayed control, P_0D_0. This treatment differed critically from the rest of the treatments. Next in order in

Table 33. Effect of different doses of leaf-applied phosphorus (with or without 'Dimecron-100') on yield characteristics and seed quality of Laha-101

P_0D_0	P_0D	P_1D_0	P_2D_0	P_3D_0	P_1D	P_2D	P_3D	$2xP_1D_0$	$2xP_1D$	C.D. at 5%
Spray treatments										
Mean of three replicates										
Seed yield (q/ha)										
10.000	12.430	11.933	11.960	12.630	12.200	12.760	13.000	12.430	16.330	0.1485
Oil yield (q/ha)										
2.6706	3.4194	3.1987	3.3001	3.5959	3.2692	3.5340	3.8014	3.4478	4.9979	0.1423
Protein yield (q/ha)										
2.320	2.986	2.788	2.870	3.148	2.835	3.045	2.923	2.980	3.721	0.3654
Oil content (% dry weight)										
26.7073	27.6186	26.8966	27.5713	27.9646	26.9286	27.6966	29.2420	27.7460	30.6060	1.0625
Protein content (% dry weight)										
23.200	24.150	23.350	24.000	24.150	23.250	23.900	22.450	24.100	22.800	0.1001

its effect was treatment P_3D which differed critically from the others. The treatments P_3D and P_3D_0 were recorded to be equal in their influence. Similarly, the effect of treatments P_0D and $2 \times P_1D_0$ was similar, whereas the value recorded for the treatment P_1D differed critically from that of other treatments. The values obtained for the treatments P_2D_0 and P_1D_0 did not differ critically from each other. The treatment P_0D_0, the control, produced the minimum yield of seeds.

4.3.2.2. Oil yield per hectare. Oil yield was significantly affected by different spray treatments. Maximum oil was found as a result of treatment $2 \times P_1D$, showing 87.2 per cent increase over the control, P_0D_0. Next to this was the treatment P_3D, the effect of which differed critically from all other treatments. Equal effect was noted in the treatments P_3D_0 and P_2D, the latter treatment was also equal in its effect to treatments $2 \times P_1D_0$ and P_0D. The treatment P_0D itself was not different critically in its effect from the treatment P_2D_0. Similarly, the treatments P_2D_0, P_1D and P_1D_0 were equal in their influence. Minimum value for oil yield was recorded in P_0D_0, the control, sprayed with water.

4.3.2.3. Protein yield per hectare. The effect of different treatments on protein yield per hectare was found to be significant. Maximum value was recorded in the treatment $2 \times P_1D$, being 60.3 per cent more than the control, P_0D_0. The remaining treatments, except the control which gave the minimum protein yield, were equal in their effect.

4.3.3. Nutrient content:

Nitrogen, phosphorus and potassium were analysed in leaves of Laha-101. The effect of different spray treatments on their contents was recorded and data are presented in Table 34.

4.3.3.1. Nitrogen. The effect of various spray treatments on the nitrogen content in leaves was found to be significant at both flowering and fruiting stages.

At flowering stage, the treatments P_2D and P_3D_0 gave the maximum and similar value. The treatment P_0D differed critically from all the treatments. Equal effect was noted in the treatments P_1D and P_2D_0. The latter treatment was equalled in its effect by the treatments 2 x P_1D_0 and P_1D_0 which were, on the other hand, equalled by 2 x P_1D. Similar values were recorded in the treatments 2 x P_1 D and P_3D. The minimum value for leaf nitrogen was recorded in the treatment P_0D_0, the control.

At fruiting stage, the treatments P_3D_0, P_0D, P_0D_0, 2 x P_1D_0 and P_2D, which gave the highest values, did not differ critically from each other. Excluding the first

Table 34. Effect of different doses of leaf-applied phosphorus (with or without 'Dimecron-100') on leaf N P K concentration of Laha - 101

Stage	Spray treatments P_0D_0	P_0D	P_1D_0	P_2D_0	P_3D_0	P_1D	P_2D	P_3D	$2xP_1D_0$	$2xP_1D$	C.D. at 5%
					Mean of three replicates						
					Nitrogen (% dry weight)						
Flowering	3.850	5.253	4.536	4.830	5.586	4.920	5.753	4.180	4.570	4.330	0.3030
Fruiting	3.666	3.786	3.393	3.443	3.896	3.201	3.486	2.730	3.576	2.953	0.4278
					Phosphorus (% dry weight)						
Flowering	0.4466	0.4533	0.4466	0.4700	0.4332	0.4266	0.4533	0.4966	0.4566	0.4966	0.0148
Fruiting	0.2633	0.3033	0.2566	0.2866	0.2366	0.2933	0.3066	0.3299	0.2966	0.3361	0.0267
					Potassium (% dry weight)						
Flowering	1.550	1.066	1.050	1.000	1.200	1.100	1.000	1.200	1.250	1.250	0.2138
Fruiting	1.200	1.500	1.000	0.800	0.600	1.050	0.716	0.700	1.000	0.900	0.2050

treatment, the rest of them were similar in their effect to the treatments P_2D_0 and P_1D_0. Similarly, the treatments $2 \times P_1D_0$, P_2D, P_2D_0, P_1D_0 and P_1D produced equal effect. It may be noted that treatment P_1D, which did not differ critically from the treatment $2 \times P_1D$, gave the lowest value. The latter was equalled by the treatment P_3D, in its turn.

4.3.3.2. <u>Phosphorus</u>. Phosphorus content in leaves was also significantly affected by the different spray treatments at flowering as well as fruiting stage.

At flowering stage, the maximum value was recorded in the treatment $2 \times P_1D$ which was equal in its effect to the treatment P_3D. Similar equal effect was also noted among the treatments P_2D_0, P_2D, P_1D_0 and P_0D_0. The treatments P_1D_0, P_0D_0 and P_3D_0 were also found equal in their effect, as were treatments P_3D_0 and P_1D.

At fruiting stage, like flowering stage, the maximum value was noted in the treatment $2 \times P_1D$, which was equalled by the treatment P_3D. This latter treatment did not show critical difference from P_2D and P_0D. The treatments P_2D, P_0D, $2 \times P_1D_0$, P_1D and P_2D_0 were found equal in their effect. Of these, treatment P_2D_0 did not differ critically from P_0D_0, the control. Similar equal effect was noted in the treatments P_0D_0, P_1D_0 and P_3D_0.

4.3.3.3. Potassium. The effect of various spray treatments on the content of potassium in leaves was found to be significant at both the stages.

At flowering stage, the maximum potassium content was found in the control, P_0D_0, sprayed with water alone. The treatments $2 \times P_1D_0$, $2 \times P_1D$, P_3D, P_3D_0, P_1D, P_0D and P_1D_0 were found equal in their effect. The values for the last five treatments did not show critical difference from the values for the treatments P_2D_0 and P_2D.

The maximum value, at fruiting stage, was recorded for the treatment P_0D. Equal effect was produced by the treatments P_0D_0, P_1D, $2 \times P_1D_0$ and P_1D_0. Excluding the first, the rest of the treatments did not differ critically from the treatment $2 \times P_1D$. Similarly, the treatments $2 \times P_1D_0$, P_1D_0, $2 \times P_1D$ and P_2D_0 were equal in their effect. The latter two treatments and P_2D and P_3D were not critically different from each other. Also, the treatments P_2D_0, P_2D, P_3D and P_3D_0 were similar in their effect.

4.3.4. Seed quality:

The effect of different spray treatments on the seed quality, namely, oil and protein percentage, was recorded after harvest. The details are given in Table 33.

4.3.4.1. Oil. Per cent oil was significantly affected by various spray treatments. The maximum oil percentage was recorded in the treatment 2 x P_1D. The value for the next best treatment, P_3D, differed critically from all other treatments. Equal effect was noted in the treatments P_3D_0, 2 x P_1D_0, P_2D, P_0D, P_2D_0 and P_1D. Similarly, except the first treatment i.e., P_3D_0, the rest of the treatments, as also P_1D and P_0D_0, the control, were similar in their effect.

4.3.4.2. Protein. The effect of different spray treatments on the protein content of the seed was found to be significant. The maximum value was recorded for the treatment P_0D and did not differ critically from the values for the treatments P_3D_0 and 2 x P_1D_0. The treatments P_2D_0 and P_2D were equal in their effect, whereas the value for the treatment P_1D_0 differed critically from all other treatments. Equal influence was exhibited by the treatments P_1D and P_0D_0. The treatment 2 x P_1D was poor in its effect and differed critically from all other treatments. The minimum value for protein percentage in seed was recorded for the treatment P_3D.

4.4. Experiment 4.

The effect of leaf-applied phosphorus and sulphur, singly or in combination on Laha-101, was studied at three stages of growth. The plants had been grown with 0, 20 or

40 kg / ha of basal P_2O_5, according to a factorial randomised design. The interaction between spray and basal dressing was also studied in this experiment. The results are briefly considered below and summarised in Tables 35 to 37.

4.4.1. <u>Growth characteristics</u>

The growth characteristics described below, were recorded at two stages of growth, namely flowering stage and fruiting stage (Table 35).

4.4.1.1. <u>Shoot length</u>. The effect of foliar application of phosphorus and sulphur, singly or in combination, as well as that of basal dressing of phosphorus, on plant length was found significant at both stages. The interaction effect between foliar application and basal dressing was also noted to be significant.

At flowering stage, the effect of the spray of sulphur alone(S) was significant. It gave 8.7 per cent higher value than the plants sprayed with phosphorus alone (P), which were even shorter than the control (W), whereas the plants sprayed with a mixture of phosphorus and sulphur were significantly taller than the control.

Regarding basal dressing, the treatments P_1(20 kg P_2O_5 /ha) and P_2(40 kg P_2O_5 / ha) produced significantly taller plants in

Table 35. Effect of leaf-applied phosphorus and sulphur, alone or in combination, with soil-applied phosphorus and of their interaction, on growth characteristics of Laha-101.

Soil treatments	Basal P_2O_5 / ha	Spray treatments: Water (W)	Phosphorus (P)	Sulphur (S)	Phosphorus + sulphur (PS)	Mean
		Mean of three replicates				
		Shoot length per plant (cm) - flowering stage				
F_0	0	138.200	152.133	162.600	164.866	154.450
F_1	20	167.200	165.533	179.333	152.200	166.066
F_2	40	172.600	149.000	164.666	171.333	164.400
	Mean	159.333	155.555	168.866	162.800	
	C.D. at 5%	Spray = 0.35197		Soil = 0.30504	Spray X Soil = 0.613008	
		Shoot length per plant (cm) - fruiting stage				
F_0	0	196.533	202.800	205.333	197.533	200.550
F_1	20	201.266	205.800	199.866	202.133	202.266
F_2	40	200.200	207.533	209.666	204.600	205.500
	Mean	199.333	205.377	204.955	201.422	
	C.D. at 5%	Spray = 0.26104		Soil = 0.2258	Spray X Soil = 0.4517	
		Fresh weight per five plants (kg) - flowering stage				
F_0	0	1.466	2.370	1.860	2.246	1.985
F_1	20	2.703	3.018	2.200	2.505	2.611
F_2	40	2.540	2.373	2.801	2.498	2.553
	Mean	2.236	2.587	2.293	2.416	
	C.D. at 5%	Spray = 0.04986		Soil = 0.04399	Spray X Soil = 0.08799	
		Fresh weight per five plants (kg) - fruiting stage				
F_0	0	1.961	1.984	1.968	2.274	2.047
F_1	20	2.190	2.837	2.193	2.509	2.432
F_2	40	2.003	2.516	3.442	2.198	2.539
	Mean	2.051	2.446	2.534	2.327	
	C.D. at 5%	Spray = 0.24931		Soil = 0.21705	Spray X Soil = 0.43409	
		Dry weight per five plants (kg) - flowering stage				
F_0	0	0.1580	0.2070	0.1840	0.2090	0.1895
F_1	20	0.2400	0.2756	0.1930	0.2626	0.2448
F_2	40	0.2620	0.1795	0.2703	0.2730	0.2461
	Mean	0.2220	0.2207	0.2158	0.2485	
	C.D. at 5%	Spray = 0.0003		Soil = 0.0002	Spray X Soil = 0.0005	
		Dry weight per five plants (kg) - fruiting stage				
F_0	0	0.4533	0.4857	0.4580	0.4923	0.4723
F_1	20	0.5133	0.6543	0.5160	0.6330	0.5792
F_2	40	0.5020	0.6450	0.8067	0.5460	0.6234
	Mean	0.4895	0.5950	0.5916	0.5571	
	C.D. at 5%	Spray = 0.03519		Soil = 0.03226	Spray X Soil = 0.06453	

comparison with F_0, the control. The maximum length was recorded for F_1. The average length of these plants differed critically from that of F_2.

It may also be noted that spray of sulphur on plants receiving 20 kg P_2O_5 / ha as basal fertiliser (treatment F_1S) gave the maximum value, whereas spray with de-ionised water on plants grown without basal dressing (F_0W) produced the shortest plants.

As noted above, at the fruiting stage also, the effects of different spray treatments as well as of basal dressing of phosphorus and of their interaction were recorded to be significant.

The effect of various spray treatments differed critically from each other. The tallest plants were obtained as a result of spray of phosphorus alone (giving 3.0 per cent more value than the control, W). The effect of the other spray treatments was in the following order: sulphur $>$ phosphorus + sulphur $>$ water only.

A gradual increase in vertical growth at the fruiting stage was noted as the basal dressing was increased from 0 kg P_2O_5 / ha to 40 kg P_2O_5 / ha.

Regarding the effect of the interaction between foliar and basal fertilisation, the F_2S plants (sprayed with sulphur and receiving 40 kg P_2O_5 / ha as basal dose) gave the maximum and the control (F_0W), the minimum response. Values recorded for all treatments differed critically from each other.

4.4.1.2. Fresh weight. Like vertical growth, the fresh weight of the plants was also noted to be affected significantly by the spray treatments as well as by basal dressing, both at the flowering and fruiting stage. So was the effect of interaction between foliar and soil application.

At the first stage, all spray treatments gave significantly higher values than the control. Maximum fresh weight was recorded in the plants sprayed with phosphorus alone (P), giving 15.6 per cent increase over the control. Next to this treatment was the effect of PS. The values for all the treatments differed critically from each other.

Among basal doses, the maximum fresh weight was recorded for the treatment F_1(20 kg P_2O_5 / ha), being 31.5 per cent higher than the control. This value differed critically from those for the other two treatments i.e. the control (F_0), which gave the minimum fresh weight, and F_2 that gave an intermediate value.

Regarding the effect of interaction, treatment F_1P gave the maximum value and F_0W, the minimum.

At the fruiting stage also, all spray treatments effected a significant but equal increase in fresh weight over the control. Similarly, both basal applications, viz. F_1 (20 kg P_2O_5 / ha) and F_2 (40 kg P_2O_5 / ha) gave equally higher fresh weight than F_0, the no-P_2O_5 control.

Taking the effect of the interaction (spray x fertiliser) into consideration, it was noted that plants receiving 40 kg P_2O_5 / ha and sprayed with sulphur alone (F_2S) gave the maximum value which differed critically from the rest of the treatments including F_0W (the no-basal P_2O_5 control sprayed with water alone) which gave the minimum value.

4.4.1.3. Dry weight. The effect of various spray and soil treatments, and of their interaction was found significant on the dry weight of plants at both stages.

At flowering stage, the values recorded for various spray treatments differed critically from each other. A spray mixture of phosphorus and sulphur gave the maximum value being 14.6 per cent more than the lowest value, recorded for the plants sprayed with sulphur alone (S).

Soil treatment F_2 (40 kg P_2O_5 / ha) gave 29.4 per cent higher value in comparison with that for F_0 (0 kg P_2O_5 / ha).

Values recorded for the different treatments differed critically from each other, the dry weight of the plants grown without fertiliser phosphate (P_0) being the lowest.

Regarding the interaction effect at this stage, the maximum response was recorded when P_1(20 kg P_2O_5 / ha)plants were sprayed with phosphorus alone. The value noted for this treatment differed critically from those for all other combinations of treatments, including P_0W (no basal P_2O_5 x spray of water) which was the least effective in dry matter production.

At fruiting stage also, all the spray treatments produced significantly more dry weight as compared with the control, sprayed with water. As compared with the water-sprayed control, plants sprayed with phosphorus or sulphur alone produced 21.6 per cent more dry matter; but the effect of the latter treatment was equal to the spray of a mixture of phosphorus and sulphur.

On the other hand, it may be noted that a gradual increase in dry weight due to basal fertiliser phosphate from 0 kg P_2O_5 to 40 kg P_2O_5 / ha was recorded, the highest dose producing 31.9 per cent more dry matter than the no-phosphate control (P_0).

Considering the interaction effect, the treatments consisting of sulphur alone in spray x 40 kg P_2O_5 / ha in soil gave the maximum value and differed critically from other treatments. Next to this treatment was the treatment F_2P, whereas F_0W produced the least dry matter.

4.4.2. Yield characteristics:

Yield characteristics, namely, seed yield, oil yield and protein yield per hectare, were recorded to be affected significantly by the treatments. The details for each are given below (Table 36).

4.4.2.1. Seed yield per hectare. The yield of seeds per hectare was significantly affected by spray treatments and basal dressings. The interaction effect was noted to be non-significant.

The plants sprayed with phosphorus alone gave the maximum yield (25.8 per cent more than the control, W). However, the value did not show critical difference from that of plants sprayed with phosphorus plus sulphur. On the other hand, the control, sprayed with water, and the plants sprayed with sulphur alone gave equal yields.

Regarding basal dressing, treatment F_0, the control, produced significantly lower yields in comparison with the yields recorded for F_1 and F_2, which had equal effect. The

Table 36. Effect of leaf-applied phosphorus and sulphur, alone or in combination, with soil- applied phosphorus, and of their interaction, on yield characteristics and seed quality of Laha-101.

Soil treatments	Basal P_2O_5 / ha	Spray treatments: Water (W)	Phosphorus (P)	Sulphur (S)	Phosphorus + sulphur (PS)	Mean
		Mean of three replicates				
		Seed yield (q / ha)				
P_0	0	16.333	23.666	19.433	19.866	19.825
P_1	20	23.466	26.333	22.166	24.666	24.158
P_2	40	20.200	25.533	20.533	25.900	23.041
Mean		20.200	25.177	20.711	23.477	
C.D. at 5%	Spray = 1.7745	Soil = 1.5369	Spray X Soil = Non-significant			
		Oil yield (q / ha)				
P_0	0	4.723	6.739	6.334	6.284	6.020
P_1	20	7.189	8.639	7.534	8.160	7.800
P_2	40	6.113	8.239	6.808	7.996	7.289
Mean		6.008	7.872	6.892	7.480	
C.D. at 5%	Spray = 0.5279	Soil = 0.4575	Spray X Soil = Non-significant			
		Protein yield (q / ha)				
P_0	0	3.765	5.680	4.373	4.374	4.548
P_1	20	5.445	6.249	5.002	5.477	5.543
P_2	40	4.800	5.867	4.457	6.448	5.393
Mean		4.670	5.932	4.610	5.433	
C.D. at 5%	Spray = 0.43115	Soil = 0.37249	Spray X Soil = 0.74793			
		Seed quality				
		Oil content (% dry weight)				
P_0	0	28.928	29.524	32.605	31.666	30.681
P_1	20	30.652	32.798	34.009	33.112	32.643
P_2	40	30.273	32.274	33.163	30.887	31.649
Mean		29.951	31.532	33.259	31.888	
C.D. at 5%	Spray = 0.50272	Soil = 0.43526	Spray X Soil = 0.87082			
		Protein content (% dry weight)				
P_0	0	23.00	24.00	22.45	21.95	22.85
P_1	20	23.25	23.75	22.75	22.20	22.99
P_2	40	23.75	23.00	21.70	24.90	23.34
Mean		23.33	23.58	22.30	23.02	
C.D. at 5%	Spray = 0.5133	Soil = Non-significant	Spray X Soil = 0.8916			

increase in yield over the control, as a result of basal dressing, was 21.8 per cent.

4.4.2.2. Oil yield per hectare. Total oil yield was significantly affected by different spray treatments and various basal dressings. Similarly, the interaction effect between the spray treatments and basal dressings was also found to be significant.

Among spray treatments, the plants sprayed with phosphorus alone or with phosphorus plus sulphur showed equal response. The remaining two treatments gave values critically different from each other as well as from these two. Plants sprayed with water only were poorest in their response, the maximum oil yield being 31.0 per cent higher than that obtained in this control.

Regarding basal dressings, it was noted that F_1 was best in its effect (giving 30.7 per cent increase over the control), followed by F_2 and F_0. All the treatments differed critically from each other in their effect on oil production in seeds.

4.4.2.3. Protein yield per hectare. The effect of various spray and soil treatments on the production of protein in seeds was found to be significant. The interaction effect between foliar and soil treatments was also recorded to be significant (Table 36).

The maximum protein yield (28.7 per cent more than the control, W) was obtained by the spray treatment consisting of phosphorus alone. Next to this was the treatment consisting of phosphorus plus sulphur in spray. The plants sprayed with water alone, or sulphur alone, showed equal effect.

Among basal treatments, F_1 and F_2 did not show critical difference in their effect. The treatment F_0 was found to be poorest in its response.

Regarding the interaction effect, the maximum value was recorded for the treatment F_2 PS, i.e. phosphorus plus sulphur in spray with 40 kg P_2O_5 / ha, which did not differ critically from the treatments F_1P (phosphorus in spray x 20 kg P_2O_5 / ha) and F_2P phosphorus in spray x 40 kg P_2O_5 / ha).

4.4.3. Nutrient content:

The nutrient content of the plants was assayed by leaf analysis at the two stages of growth. The data regarding the percentages of nitrogen, phosphorus and potassium present in fully expanded, mature leaf blades, are briefly described below and summarised in Table 37.

4.4.3.1. Nitrogen. The effect of different spray treatments was found to be significant at flowering as well as fruiting stage. Basal dressing affected the concentration of nitrogen

Table 37. Effect of leaf-applied phosphorus and sulphur, alone or in combination with soil-applied phosphorus, and of their interaction, on leaf N P K concentration of Laha-101.

Soil treatments	Basal P_2O_5 / ha	Spray treatments: Water (W)	Phosphorus (P)	Sulphur (S)	Phosphorus + sulphur (PS)	Mean
		Mean of three replicates				
		Nitrogen (% dry weight) - flowering stage				
P_0	0	3.866	4.791	4.016	5.291	4.491
P_1	20	4.583	4.583	3.641	4.950	4.430
P_2	40	4.541	5.125	4.800	5.700	5.041
Mean		4.330	4.833	4.152	5.313	
C.D. at 5%	Spray = 0.3725	Soil = 0.3226	Spray X Soil = Non-significant			
		Nitrogen (% dry weight) - fruiting stage				
P_0	0	2.066	4.108	3.183	2.558	2.979
P_1	20	2.725	3.833	2.641	2.391	2.897
P_2	40	2.641	3.675	2.483	2.808	2.902
Mean		2.477	3.872	2.769	2.586	
C.D. at 5%	Spray = 0.4135	Soil = Non-significant	Spray X Soil = Non-significant			
		Phosphorus (% dry weight) - flowering stage				
P_0	0	0.440	0.504	0.401	0.454	0.449
P_1	20	0.402	0.529	0.405	0.525	0.465
P_2	40	0.440	0.450	0.438	0.528	0.464
Mean		0.427	0.494	0.415	0.502	
C.D. at 5%	Spray = 0.0440	Soil = Non-significant	Spray X Soil = Non-significant			
		Phosphorus (% dry weight) - fruiting stage				
P_0	0	0.285	0.332	0.221	0.312	0.287
P_1	20	0.280	0.440	0.261	0.352	0.333
P_2	40	0.296	0.400	0.290	0.394	0.345
Mean		0.287	0.390	0.257	0.352	
C.D. at 5%	Spray = 0.0352	Soil = 0.0293	Spray X Soil = Non-significant			
		Potassium (% dry weight) - flowering stage				
P_0	0	1.433	1.500	2.556	2.256	1.933
P_1	20	1.806	2.150	2.200	1.100	1.812
P_2	40	2.450	1.400	1.600	2.200	1.912
Mean		1.894	1.683	2.116	1.850	
C.D. at 5%	Spray = 0.1789	Soil = Non-significant	Spray X Soil = 0.3109			
		Potassium (% dry weight) - fruiting stage				
P_0	0	0.800	0.750	0.750	0.550	0.712
P_1	20	0.600	0.700	0.600	0.500	0.600
P_2	40	0.800	0.700	0.650	0.800	0.737
Mean		0.733	0.716	0.666	0.616	
C.D. at 5%	Spray = Non-significant	Soil = Non-significant	Spray X Soil = Non-significant			

in leaves significantly only at the flowering stage, whereas, the interaction between spray and solid fertiliser did not have significant effect at either of the two stages.

At flowering, the spray of the mixture of phosphorus and sulphur gave the highest value. Next to this treatment was the effect of spray of phosphorus alone. It was noted to be significantly higher in comparison with the effect of sulphur spray which showed equal effect to that of water spray.

Among basal doses, the highest nitrogen concentration was recorded for F_2, the higher of the two basal doses of phosphate. It differed critically from the effect of the other two treatments which equalled each other.

At the fruiting stage, the leaves of the plants sprayed with phosphorus only gave the maximum nitrogen concentration. The remaining spray treatments showed equal effect.

4.4.3.2. <u>Phosphorus</u>. The concentration of phosphorus in plant leaves was significantly affected by various spray treatments both at flowering and fruiting stage. The soil treatment had significant effect at the later stage only, whereas, the effect of the interaction between foliar and soil application was found to be non-significant at both stages.

Whereas the effect of the spray of phosphorus plus sulphur and phosphorus alone was recorded to be equal at the flowering stage, the value for the spray of sulphur alone at the fruiting stage was critically lower than that for the other three treatments and was found to be equal to the value for the spray of water alone.

Regarding the significant effect of the basal doses of phosphorus at the fruiting stage, it may be added that the effect of the treatment F_2 was not critically different from that of F_1, with F_0 giving the minimum value.

4.4.3.3. Potassium. The effect of various spray treatments on the potassium concentration in leaves at flowering stage was recorded to be significant. The effect of basal dressing was non-significant but the interaction between foliar and basal treatments was noted to be significant, while at fruiting stage, the effect of foliar spray, basal dressing and interaction was found to be non-significant.

At the flowering stage, maximum potassium content was determined in the leaves by the treatment consisting of sulphur alone in spray. The values recorded for the plants sprayed with water only or with a mixture of phosphorus and sulphur were not critically different. On the other hand, the effect of the treatment consisting of phosphorus and sulphur or phosphorus alone in spray was recorded to be equal.

Regarding the interaction effect, the maximum value was recorded for the treatment P_0S i.e. sulphur alone in spray with no solid fertiliser phosphorus. Next to this was the value noted for the treatment P_2W i.e. water alone in spray and 40 kg P_2O_5 / ha as basal dose.

4.4.4. Seed quality:

To assess the effect of various doses of leaf-applied phosphorus and sulphur on seed quality of Laha-101 grown with three basal doses of phosphorus, oil content and protein percentage were estimated. The data are summarised in Table 36 and are briefly presented below:

4.4.4.1. Oil. The oil content of seeds was significantly affected by different spray as well as soil treatments. The interaction between foliar and soil application was also noted to affect the percentage of oil in the seeds significantly.

The plants sprayed with sulphur alone gave the maximum value i.e. about 10.0 per cent increase over the plants sprayed with water. Next to this was the value for the treatment consisting of phosphorus plus sulphur which did not differ critically from the value for the treatment consisting of phosphorus alone. The plants sprayed with water showed the poorest response in this respect.

Among basal dressings, the treatment consisting of 20 kg P_2O_5/ ha (P_1) was superior as compared with the others, showing approximately 7.0 per cent increase over the control. The minimum value was recorded for the untreated control i.e. the plants without added P_2O_5. The effect of all the treatments differed critically from each other.

The interaction between sulphur alone in the spray and of basal phosphorus at the rate of 20 kg P_2O_5 / ha was recorded to be the best. The effect of sulphur spray with the higher fertiliser dose (40 kg P_2O_5 / ha) gave a value next to this.

4.4.4.2. Protein. The effect of various spray treatments on protein percentage of seeds was found to be significant. The basal dressings did not show any significant effect, whereas, the interaction between the effect of spray and solid fertiliser was noted to be significant.

Among spray treatments, the sprays consisting of phosphorus alone or water or phosphorus plus sulphur produced equal effect differing critically from the treatment consisting of sulphur alone in spray.

As for the interaction between spray and basal treatments, the treatment P_2PS i.e. phosphorus and sulphur in spray with 40 kg P_2O_5 / ha as basal dressing was found to be the best but its effect did not differ critically from three of the remaining eleven treatment combinations namely F_0P i.e., phosphorus alone in spray and no fertiliser in soil, F_1 P i.e. phosphorus alone in spray and 20 kg P_2O_5 / ha in soil and F_2W i.e. spray of water with 40 kg P_2O_5 / ha added in the soil.

Chapter 5

DISCUSSION

C O N T E N T S

5. DISCUSSION

5.0. Introduction:

Agriculture is considered today an art as well as science. This is understandable in view of the long history of the subject: the story of agriculture, in fact, being the story of civilisation itself. For centuries, man has depended almost entirely for his subsistence on this most ancient of occupations, in all parts of the world. Nevertheless, it is astonishing to note that, inspite of this pre-emminence, crop production remained a more or less trial and error affair until the beginning of the present century. A natural calamity, like drought, flood or epidemic of a plant disease, would mean death and disaster for millions of consumers during a lean year, while a bumper harvest would cause a recession that would simply ruin the farmer himself. The attainment by agriculture, in recent decades, of the status of a well defined and discrete industry, based on sound economic as well as scientific principles, is, therefore, a landmark in its chequered history and a most healthy step in the right direction.

An aspect of foremost importance in this regard is the constant endeavour of farm scientists to try and evolve, by selection or breeding, new varieties of crop plants that are most suited for the environment in which they are meant to be grown. This takes into account a number of desirable attributes such as early (or, sometimes, late) ripening, resistance to disease, drought, frost, heat and lodging on the one hand, and high yielding capacity, coupled with better quality, on the other.

From the economic point of view, a sound policy of price support, in addition to facilities for marketing, is essential. Also, easy availability of inputs (including seed, fertiliser, power and irrigation water) at reasonable cost are factors of paramount importance for ensuring a good balance between production and price.

The "Green Revolution" of the last decade has no doubt brought about a radical improvement on the food front in our country; but the recent 'oil crisis' has more or less neutralised its benefits due to an exorbitant rise in the cost of energy production which has resulted in the spiralling of the price of the inputs themselves.

It is, therefore, highly desirable that the attention of the present day scientific farm workers be focussed on these dreaded problems of inflationary trends in crop production. It can not be overemphasised that one of the remedies lies in exercising the most economic use of inputs without sacrificing the yields. The experiments described in the preceding pages were based on this twin objective of fertiliser economy and optimum yield.

It seems relevant at this stage to point out that the technique of replacing large quantities of soil-applied phosphorus with considerably less amounts of phosphorus in the spray adopted in these experiments is based on sound experimental evidence. The use of P^{32} has established beyond doubt that leaves are capable of ready absorption and utilisation of phosphorus and that the unutilised excess is subsequently translocated to other plant parts (Biddulph, 1951; Silberstein and Wittwer, 1951/to cite the pioneer workers only, see also reviews by Boynton, 1954; Thorne, 1954; Wittwer and Teubner, 1959; Bould, 1963 and Samiullah, 1971).

5.1. Experiment 1.

In the first field trial, the work started by Samiullah (1971) was extended to study the effect of a broader range of spray phosphorus (cf. Afridi and Samiullah, 1973). Thus 5.460 kg P_2O_5 / ha and 10.920 kg P_2O_5 / ha were sprayed on plants receiving 0 and 30 kg basal P_2O_5 / ha in addition to the lower doses (0, 1.365 and 2.730 kg P_2O_5 / ha) used by these earlier workers.

5.1.1. Growth characteristics:

It would be noted from Tables 8 to 13 that spray phosphorus had a beneficial effect on the growth of NP 13 barley. It may, however, be pointed out that, although at heading stage, the lower doses had the most beneficial effect on the two more important growth characteristics, namely, tiller production and dry matter formation, fresh weight was increased most with the highest dose. On the other hand, all three growth characteristics were enhanced most at milky grain stage, by the two higher doses. This differential effect of spray phosphorus noted at heading and milky grain stage of growth might be due to a reduction in the capacity (on the basis of percentage of phosphorus absorbed), of barley leaves as they matured. Similar observations have been reported for soyabean by Ahlgren and Sudia (1964) and for maize by Datta and Vyas (1967). It is, therefore, implied that the amount of leaf-applied phosphorus required for optimum growth depends upon the stage of the crop at which it is applied, lower doses being sufficient at the earlier stages and higher doses being required at later stages. It is also noteworthy that Das (1959) found a better response in barley to lower doses of basal phosphate at heading stage of growth.

The effect of soil-applied phosphorus on growth characteristics of barley (and other crops) is well known. Enhanced growth of barley by the application of basal phosphorus compared with the no-phosphorus control, as noted in the present study, has been reported by Van der Paauw (1952), Das (1959), Fujiwara and Ohira (1960), Lal and Subba Rao (1960), Sen (1960), Safaya (1971) and Samiullah (1971), among recent workers.

Like the findings of Samiullah (1971), the effect of the interaction between spray and basal phosphorus in the present experiment was significant, the best combination being $F_{30}P_3$ and $F_{30}P_4$. The two higher doses of spray phosphorus X sub-optimal basal phosphorus were optimum for the three growth characteristics studied, particularly at the later stage of growth.

5.1.2. Yield characteristics:

In barley, as in other cereals, it is the final yield that is the primary concern of the grower. Grain yield, however, depends upon a number of plant characters including tillers, leaves and glumes as well as other ear characteristics. Whereas, it is desirable to increase the number and size of the green aerial parts to ensure maximum photosynthetic activity, it is equally important that the products of this activity are readily transported to the developing grain and properly stored there ensuring maximum economic yields. The ear characteristics play an equally important, albeit complicated, role in this process. Increased fertility of the ovaries if not coupled with an increase in the number of ears and spikelets would not ensure high yields. Similarly, an increase in ear weight alone without simultaneous increase in the number of grains per ear would be meaningless. However, all these efforts at maximisation of yield would be futile if unaccompanied by an increase in the volume and test weight of the grain which are a good measure of the capacity for translocation and storage of photosynthates, the so-called "grain filling" process.

The data regarding final yields were mostly significant and clear-cut in the present investigation (Tables 14 to 22). Higher yields were obtained by the spray of all the doses of phosphorus irrespective of the stage of growth selected for spraying compared to the control sprayed with water, confirming the findings of Afridi and Samiullah (1973). It may be mentioned here that the two stages of growth in barley at which phosphorus was sprayed (heading and milky grain stage) represent a period of greatest metabolic activity of the plant. It is at these stages that fertilisation takes place and grains start developing putting the highest demand for their growth on all other organs. The ready availability from the spray of phospherus (the key element for all energy requiring processes) at the site of photosynthetic and translocatory activity would, therefore, ensure faster and sustained grain filling. In this connection mention may be made of the observation of Mitchell (1957) who noted that the phosphorus in the above ground parts of wheat, grown with basal fertiliser, migrated to the heads of the plant as it matured. In the present study, therefore, the application of soluble phosphate to the aerial parts of barley grown with a sub-optimal dose of solid phosphatic fertiliser (30 kg P_2O_5 / ha) readily provided for the sprayed phosphorus a good opportunity to play the vital roles assigned to it ensuring ultimately higher grain yields.

It is interesting to note here that, as in the case of growth characteristics at milky grain stage, the two higher doses of phosphorus (P_3 and P_4) proved optimum for final (total as well as grain) yields, irrespective of the stage at which spray was applied. It would be noted from Tables 14 to 18 that P_3 and P_4 significantly enhanced ear number and weight as well as spikelet and grain number per ear. These are the main characteristics that contribute towards final grain yield-hence the observations noted above.

The case of 1,000 grain weight was rather interesting in this context. All spray phosphorus treatments proved beneficial for this characteristic. However, the higher doses, P_3 and P_4, gave a lower test weight than did P_1 and P_2 (Table 19).

This is contrary to the effect of various doses of spray phosphorus on the other yield characteristics noted above. This inverse relationship of yield response to 1,000 grain weight is, in all probability, a reflection on the genetic make-up of NP 13 barley. There is no doubt that the higher doses of spray phosphorus produced the highest number (and weight) of fertile ears, as well as, of fertile spikelets and grains. However, the ear of this variety seems to possess a low capacity for expansion. The assimilates, being preferentially transferred to the developing ear under the circumstances (Yatagawa, 1954; Afridi and Samiullah, 1973), therefore, got diffused throughout its various parts at the expense of individual grains which probably did not get enough space for expansion in the panicle due to mutual competition. Another explanation worth considering is that, in this variety, the developing grains (rather than the ears) might lack the capacity for expansion beyond a (low) limit for the grain-filling process to continue unabated. Consequently, the assimilates after being transferred from the sites of production would get diverted to parts of the ear other than the grain itself.

The addition of 30 kg P_2O_5 / ha as basal dressing increased the final yields of grain and straw over the no/-P_2O_5 control. This would be expected to result due to the cumulative effect of added phosphorus on all the growth and yield characteristics studied including the significant increase in test weight of treated, over untreated plants. This observation is most expected as phosphorus is known to be involved in almost all the physiological activities of the plant at all stages of growth and development (Hewitt, 1963; Devlin, 1975).

For the effect of spray x basal phosphorus it may be mentioned that, although the data for final yields were not significant, the general trend on yield characteristics was a beneficial effect of the two higher doses of spray phosphorus in the presence of added basal phosphorus. This is also to be expected in view of the separate beneficial effects of the main plot and sub plot treatments on these yield characteristics.

As a generalisation it may be concluded that the data in Experiment 1 reveal that doses P_3 and P_4 (5.460 and 10.920 kg P_2O_5 / ha) which showed equal effect in most cases, were superior to the others for growth and yield of NP 13 barley. These doses, it may be recalled, were higher than those employed by Samiullah (1971) - see also Afridi and Samiullah (1973). The results thus sustained the hypothesis of the present author that application of a broader range of doses of spray phosphorus might help in deciding the optimum dose for highest yields under the constraints of fertiliser economy (p. 4).

5.1.3. Nutrient content of leaf.

The effect of doses of spray phosphorus on leaf nitrogen was opposite to that on leaf phosphorus, the lower doses (P_1 and P_2) enhancing leaf nitrogen and the higher doses (P_3 and P_4) increasing leaf phosphorus concentration most. A similar observation on the relationship of spray phosphorus to leaf nitrogen and phosphorus was made by Samiullah (1971). It is also supported by work on fertiliser phosphorus in barley (Burd, 1919; and Brenchley, 1929 among the earlier, and Das, 1959; Mac Leod, 1969; Safaya, 1971 and Samiullah, 1971, among the more recent, workers). The findings of the present author, with regard to the effect of the application of basal phosphorus, are also in line with the data of these authors. 30 kg P_2O_5 / ha decreased leaf nitrogen but enhanced leaf phosphorus, when compared with the control.

Leaf potassium data were significant only at the heading stage; but did not show any clear-cut trend as regards the effect of phosphorus spray. This, coupled with the meagre data available, rendered their interpretation difficult.

5.2.3. Experiments 2 and 3.

The second and third field trials on barley (var. NP13) and mustard (var. Laha-101) respectively were laid out side by side. No phosphate or potash was added to the soil at the time of sowing. However, sufficient nitrogen was added as basal dressing. The treatments enhanced most of the vegetative and yield characteristics significantly (Tables 29 to 34).

5.2.3.1. <u>Vegetative characteristics in barley and mustard</u>:

The spray treatments eliciting better growth response, as shown by the data on vertical growth and total weight as well as tiller production (in barley only), were those containing large amounts of phosphorus with "Dimecron-100". It may be noted that two sprays of the lowest dose (2 x P_1D) gave the best results. In NP 13 barley (but not in Laha-101), spray of "Dimecron-100" alone also showed good response regarding growth characteristics (Tables 29 and 32).

This effect of "Dimecron-100" is not hard to understand. The crops of barley and mustard were both grown without basal phosphatic fertiliser to effect maximum economy. Naturally, they would have suffered from some deficiency of phosphorus throughout their life. "Dimecron-100" possesses 10 per cent phosphorus by weight (see p. 32). The beneficial effect of sprays containing "Dimecron-100" alone on growth may, therefore, be to some extent the manifestation of the effect of this phosphorus in the insecticide. The ready availability of phosphorus to the leaves of these phosphorus-starved plants from "Dimecron-100" or phosphatic spray would be expected to enhance their growth and development. Moreover, as mentioned earlier on p. 106, the stages of growth at which sprays were applied on the shoots coincided with a period of great metabolic activity of these plants (Afridi and Samiullah, 1973)- hence the observed response to "Dimecron-100" and phosphatic sprays. Also, the observed beneficial effect of "Dimecron-100" on tiller number and plant weight in barley might probably be due to the stimulating effect of phosphamidon, the active ingredient of this insecticide, on cell division (Anonymous, 1967, p. 90). An enhancement in the rate of cell division would result in quick increase in cell number promoting tiller production and enhancing the volume of the aerial parts. This would naturally result in increased fresh as well as dry weight of the treated plants.

Mustard, however, did not show the same response to "Dimecron-100" alone at any stage of growth. The reason for this discrepancy seems to lie in the morphological and physiological differences between the two crops: mustard, with its broader and thinner leaves and taller shoots, possibly being more prone to phosphorus deficiency than barley with its narrow, stiff leaves and tillering habit, the crops having been grown with basal nitrogenous fertiliser only.

Another reason for the beneficial effect of "Dimecron-100" (alone or in combination with phosphorus) could be the observation that both barley and mustard are normally heavily infested with aphids at the stages of growth selected for spray application of phosphorus. These pests account for the removal of large quantities of photosynthates resulting in retarded growth and drastically decreased yields. The application of "Dimecron-100", an effective insecticide for aphid control, would, therefore, ensure their complete annihilation thereby restoring the normal rate of growth and dry matter production.

5.2.3.2. Yield characteristics in barley:

For the sake of convenience, the effect on the yield characteristics of the two crops, which differ widely in details, are discussed separately below.

Like growth characteristics, total barley yields were enhanced most by the application of relatively large quantities of phosphorus in the presence of "Dimecron-100" (Table 30), the best treatment again being 2 x P_1D. The contributing factors for this enhancement in grain yield were better vegetative growth, followed by significantly higher ear number, ear weight and 1,000 grain weight. Even the characters affected non-significantly by the treatments, namely, ear length and spikelet and grain number per ear, exhibited the same trend.

5.2.3.3. <u>Yield characteristics and seed quality of mustard</u>:

The best seed and oil yields were obtained with treatments $2 \times P_1D$ and P_3D. Protein yield was, however, favoured most by $2 \times P_1D$, a large number of other treatments showing equal lower effect (Table 33).

The percentage of oil in the seed was also higher in treatments $2 \times P_1D$ and P_3D while that of protein showed a totally reverse trend. This is understandable as the carbon skeletons are known to be preferentially utilised for oil production in these crops resulting in a retardation of the process of protein synthesis.

Similar observations on the effect of spray phosphorus (in the presence of nitrogen and potassium) on the seed and oil yield of sunflower have been reported by Čalgóczi (1969). Bose (1957), working with mustard; Sen and Lahiri (1960), with sesame; Sen and Sarkar (1968), with mustard; and Dembiński <u>et al.</u> (1969) and Horodyski and Piecka (1970), with rape; came to the same conclusion in their experiments with phosphorus applied to the soil. Moreover, an inverse relationship between oil content and protein content of mustard seed has been reported by Mehrotra <u>et al.</u> (1972). It may not be irrelevant to note here that Simanskiĭ (1961), Sinha <u>et al.</u> (1961, 1962) and Arora and Bhatia (1970) noted that application of basal nitrogenous fertilisers increased the protein content of seeds at the expense of their oil content in sunflower and mustard, respectively.

5.2.3.4. Nutrient content of leaves of barley and mustard:

As in the first experiment (on barley), the data on leaf NPK reveal that spray of higher phosphorus containing doses decreased leaf nitrogen but increased leaf phosphorus, particularly at the later stage of growth in both crops. Regarding leaf potassium, which was significantly affected by the spray of phosphorus only at the early stage in barley and at both stages in mustard (Tables 31 and 34), it would be noted that, unlike Experiment 1 in which the effect was not well defined, potassium concentration in the leaves of the two crops was generally decreased by higher doses of spray phosphorus. This is in conformity with the significant findings of Samiullah (1971) in an experiment in which phosphorus was sprayed on the foliage and of Das (1959), Richards and Rees (1962), Safaya (1971) and Samiullah (1971) in experiments involving graded doses of soil-applied phospherus.

5.4. Experiment 4.

This last field trial on Laha-101 was based, in part, on the findings of Experiment 3, in which it was established that two consecutive doses of spray phosphorus, the first at flowering and the second at fruiting stage, were best for growth and yield of this variety of mustard (pp. 80, 81 and 82). In addition, sulphur was included in the spray programme as this element is known to be very intimately associated with the growth and metabolism of plants, particularly of oil crops (Gilbert, 1951; Nason and McElroy, 1963; Bandurski, 1965; Devlin, 1975). The experiment was laid out according to a factorial randomised design to include four spray and three basal treatments, so as to obtain maximum information regarding the nutrient needs of the crop.

5.4.1. <u>Vegetative characteristics</u>

The data in Table 35 reveal that all three vegetative characteristics studied were significantly affected by the spray treatments as compared with the control that had received spray of water only. The order of the beneficial effect of spray was: phosphorus > sulphur > phosphorus plus sulphur.

The enhancing effect of phosphorus spray on the growth and development of mustard has already been discussed on p. 112. Sulphur, is known to be readily absorbed by leaves from the atmospheric gases (Boynton, 1954; Wittwer and

Teubner, 1959; Furrer, 1967) and from solutions (Biddulph, 1956; Bukovac and Wittwer, 1957). Once inside the leaf, it is readily translocated to other aerial organs but more slowly to roots. It may, however, be kept in mind that the rate of absorption and translocation from foliar spray is slightly less for sulphur than for phosphorus (Biddulph, 1956; Bukovac and Wittwer, 1957). Moreover, the sulphur absorbed by leaves is known to be metabolised into various organic compounds (Wittwer and Teubner, 1959) possibly by the same mechanisms as utilise sulphur absorbed through the roots.

In the present study, compared with the control, sprayed with water, growth of Laha-101 was generally enhanced by spray of sulphur or of sulphur plus phosphorus almost to the same extent as by spray of phosphorus alone which showed the best effect (Table 35). One of the reasons for this stimulating effect of sulphur might have been its 'hidden' deficiency in the experimental plants, the soil having received no sulphur in fertilisers for two consecutive years (see pp. 34 and 35). However, it may be admitted that no attempt was made to analyse the soil for its sulphur content prior to or during the trial. Data for the effect of basal phosphorus on growth characteristics reveal that P_1, the lower dose (20 kg P_2O_5 / ha), was generally better than P_2 (40 kg P_2O_5 / ha) for shoot length and fresh weight at the flowering stage but the trend was reversed at the fruiting stage. It is noteworthy that dry matter production was accelarated most by the higher dose, P_2. This observation was not unexpected due to low available soil P (Table 5) and confirmed the findings of Sen and Sarkar (1968) on the effect of solid phosphatic fertiliser applied to mustard plants grown in sand culture. They found a linear relationship between the dose of phosphorus applied to the pots and the growth characteristics noted, including height and dry weight.

Regarding the interaction effect, soil-applied phosphorus x spray, it may be noted that spray of water on plants grown without added basal phosphorus gave the poorest performance. P_1S (20 kg P_2O_5 + 1 kg spray sulphur/ha) proved superior to all other treatments for shoot length, while P_1P (20 kg P_2O_5 + 2 kg spray P_2O_5 /ha) was best for fresh and dry weight at the early stage. However, at the later stage, P_2S (40 kg P_2O_5 + 2 kg spray sulphur/ha) enhanced all three characteristics most. It may be stated that the optimal range of solid phosphatic fertiliser for Lahá-101 lies between 30 and 40 kg P_2O_5 / ha under local conditions (Afridi, unpublished). A low dose (20 kg P_2O_5/ha), combined with additional phosphorus by spray, might have sufficed for young plants for fresh and dry weight. However, as the plants grew older, their phosphorus requirement increased and only the higher dose could prove sufficient for sustained growth and dry matter production. The role of sulphur, however, can not be pin-pointed with our meagre knowledge of the sulphur metabolism in plants. It may be conjectured though that the observed enhancement in the growth of plants sprayed with sulphur might have been because of its involvement in protein synthesis on which all growth processes depend.

5.4.2. Yield and quality:

Data regarding total yield of seed, oil and protein as well as oil and protein percentage, collected at harvest (Table 36), reveal that spray of phosphorus alone was best for seed, oil and protein yield of this variety, with spray of phosphorus plus sulphur being equally good only for the first two characteristics. However, spray of sulphur alone was slightly detrimental for all the yield characteristics. This is understandable with reference to the adverse effect of spray of sulphur on seed protein percentage as revealed by the table. It may also be noted that, although this treatment enhanced the percentage of oil content in the seed most, a drastic decrease in the total seed yield rendered this treatment inferior to the other two - hence the lower oil yield noted above. Lastly, it may also be pointed out that the treatments encouraging the percentage of oil in the seed reduced the percentage of seed protein most and vice-versa, which is in conformity with known facts (see also p. 114).

Data on the effect of basal treatments revealed that both 20 and 40 kg P_2O_5 / ha were equally favourable for seed and protein yield, while oil yield was optimum with the lower dose through its favourable effect on oil percentage in seeds. Similar findings had been obtained in Experiment 3 on mustard discussed above (p. 114). The beneficial effect of the lower dose (20 kg P_2O_5 / ha) is in line with the findings of Wankhede et al. (1970) and Nalamwar et al. (1972) who noted an actual reduction in seed and oil yield of rape and groundnut, respectively, with higher doses of solid phosphatic fertiliser.

The data regarding the effect of interaction of spray of nutrients and soil-applied phosphorus reveal that, whereas seed and oil yield was optimum with F_1P (lower basal dose of phosphorus plus spray of phosphorus), protein yield was maximum with the combination F_2PS (higher basal dose of phosphorus plus spray of a mixture of phosphorus and sulphur). This is understandable in view of the observation that spray of sulphur alone gives a poor performance as compared with that of phosphorus (p. 119) while, on the other hand, combined spray of phosphorus and sulphur would certainly be expected to promote protein synthesis, as noted earlier and below.

Regarding seed quality, F_1S (lower dose of basal phosphorus plus spray of sulphur) proved best for oil percentage, whereas, F_2PS enhanced the protein percentage most. This would be expected in view of the clear-cut separate effects of spray and soil application noted earlier (p. 117 and 118).

5.4.3. Nutrient content:

As in the case of growth characteristics, leaves of Laha-101 were analysed for their NPK content at two stages of growth (Table 37).

Their nitrogen and phosphorus contents were noted to be decreased most by spray of sulphur; while, on the other hand, spray of phosphorus proved best at both stages of growth. An apparent explanation for this observation on leaf nitrogen and phosphorus, in the presence of sprayed sulphur, might be an increased synthesis of proteins, nucleoproteins and other organic sulphur containing compounds which would subsequently migrate to the inflorescence depleting the leaves of their normal nitrogen and phosphorus content. Leaf potassium, which was significantly affected only at the flowering stages, showed the reverse trend. Although there is no reference in the literature on the effect of spray of sulphur on leaf potassium (or on leaf nitrogen and phosphorus, for that matter), the effect of spray of phosphorus is known to be detrimental for leaf potassium content, as discussed earlier (p. 115). Lastly, it may be stated that the effect on nutrient content of soil-applied phosphorus and its interaction with spray can not be included in the present discussion due to paucity of significant data.

5.5. <u>Proposed future work</u>:

It is evident from the foregoing discussion that many of the points raised in the introductory chapter have been clarified. However, as the investigations proceeded, several new problems emerged. Some of these are given below as they could not be tackled during the short time available to the present investigator. None-the-less, their emminence cannot be over-emphasised and it is proposed to commend their inclusion in the investigations being planned to be taken up in the near future.

For barley (as well as for mustard), extensive studies taking more high yielding varieties are warranted, on the basis of the results of the first experiment, to establish the optimum combination of spray and basal phosphorus doses for different varieties, from the point of view of fertiliser economy.

In view of the importance of the nutritive value of seed proteins, it is also considered desirable to investigate the combined affect of spray of phosphorus and/or sulphur with nitrogen, in the presence of "Dimecron-100" and other pesticides. Further, analysis of the essential amino acid composition of these seed proteins, as affected by various treatments, would enhance the quality of investigation.

The work with sulphur sprays on mustard having yielded encouraging results in the present investigation, it is suggested that it should be extended to include other oil yielding crops such as sunflower, groundnut and soya bean in the future. From the purely academic point of view, it would be very interesting to include radioactive sulphur in the spray mixture to trace the uptake, translocation and subsequent metabolisation of this important (albeit neglected) macro-nutrient by these oil crops under Indian conditions.

Lastly, it goes without saying that applied physiological studies of the type presented in this thesis would never be considered complete unless factors other than fertilisers also are properly investigated simultaneously. Thus, a critical study of the effect of such agronomic variables as date of sowing, plant density, frequency of irrigation, etc. on the growth, yield and seed quality of these important crops should be expected to yield results of considerable national (and possibly international) importance.

Chapter 6

S U M M A R Y

6. S U M M A R Y

6.0. The importance and genesis of the research problem "Studies of the effect of foliar nutrition on the growth and yield of barley and mustard" has been briefly considered (Chapter I).

Up-to-date literature pertaining to phosphorus (P) applied basally or serially on cereals and oil crops (with particular emphasis on barley and mustard) has been critically reviewed and the lacunae in the present state of knowledge pointed out (Chapter II).

The details of the materials used, statistical designs of the four field experiments carried out, chemical and analytical methods employed and statistical analyses of data obtained have been given (Chapter III).

6.0.1. The present investigation comprised a detailed study of the effect of foliar nutrition on the growth and yield of barley (*Hordeum vulgare* L.) var. NP13 and mustard (*Brassica juncea* (L.) Czern and Coss.) var. Laha-101. Four field trials were undertaken from 1969 to 1974 during the 'rabi' (winter) seasons.

Observations were made at two stages of growth in barley and mustard, 70 and 90 days after sowing. In the former, they coincided with the heading and milky grain stages and in the latter with flowering and fruiting.

6.1. In Experiment 1 (1969-70), the effect of various doses of P (applied either as spray or as basal dressing) on growth and yield characteristics and leaf NPK content of NP13 barley was studied. The experiment was based on a split plot design.

In Experiment 2 (1971-72), the effect of different doses of leaf-applied P with and without "Dimecron-100", a commercial insecticide, on NP13 barley was investigated. The parameters studied included growth characteristics, yield characteristics and leaf NPK content. This experiment was based on a simple randomised block design.

In Experiment 3 (1971-72), the treatments were the same as in Experiment 2. The characteristics studied included growth, yield, leaf NPK content and seed quality of Laha-101. This experiment was also based on a simple randomised block design.

In Experiment 4 (1973-74), the effect of phosphorus and sulphur (S) applied as spray, alone or in combination, and of three doses of soil-applied P on growth and yield characteristics, leaf NPK content and seed quality of Laha-101 was studied. This experiment was laid out according to a factorial randomised design.

6.1.1. In Experiment 1, all three growth characteristics studied, namely, tiller number, fresh weight and dry weight were found to be favourably affected both by foliar, as well as, by soil P. Regarding the spray treatments, at heading stage, the lower doses 1.365 kg and 2.730 kg P_2O_5 / ha (P_1 and P_2) were found to stimulate tiller production more than the two higher doses (P_3 and P_4). However, at milky grain stage, P_3(5.460 kg P_2O_5 / ha)and P_4 (10.920 kg P_2O_5 / ha) gave higher tiller number per plant. Fresh weight also was more with P_3 and P_4 at both stages. Dry weight was optimum in treatments P_1 and P_3. Treatment P_4 gave only a slightly poorer performance at heading stage, but gave convincingly superior results at milky grain stage (Tables 8 to 13).

6.1.2. As would be expected, basal dressing with 30 kg P_2O_5 / ha (P_{30}) proved to be significantly better than the no-phosphorus treatment (P_0) for the three growth characteristics studied, so also was the interaction effect between sub plot and main plot treatment. A noteworthy feature of the effect on growth characteristics studied at either stage was the general benefit derived by spray of either of the two higher doses (P_3 and P_4) applied with or without basal P (Tables 8 to 13).

6.1.3. Yield characteristics (with the exception of ear length and straw yield) were significantly enhanced by P spray, the optimum doses again being P_3 and P_4, applied at either of the two stages (Tables 14 to 22).

6.1.4. Like growth characteristics, basal dressing with 30 kg P_2O_5 / ha (F_{30}) proved significantly superior to 0 kg P_2O_5 / ha (F_0) for all yield characteristics studied (Tables 14 to 22).

6.1.5. In general, N, P and K content of leaves was significantly enhanced by spray P at both stages (with the exception of K at milky grain stage, when the results were non-significant). It may be mentioned that the higher doses (P_3 and P_4) were conducive to optimum leaf P whereas leaf N was highest in treatments containing the lower doses of spray P (P_1 and P_2) at both stages. However, K concentration (at heading stage) showed some inconsistency (Tables 23 to 28).

6.1.6. The main feature of split plot was the significant decrease in the level of N and increase in that of P and K by 30 kg P_2O_5 / ha applied at the time of sowing (Tables 23 to 28).

6.1.7.1. Regarding interaction effects, at heading stage, the best combination for leaf N was F_0P_2 and $F_{30}P_2$; but, at milky grain stage, the higher spray doses reacted best with both levels of solid P (see, for example, data for F_0P_3 and $F_{30}P_4$). Another notable observation was the depressing effect of the interaction between fertiliser and spray P on the leaf N concentration.

6.1.7.2. For leaf P (which was affected significantly only at the milky grain stage), the combinations F_0P_4, F_0P_3 and $F_{30}P_4$ proved superior in general to the other combinations. At the same level of spray (main plot), basal dressing with 30 kg P_2O_5 / ha enhanced leaf P concentration thus exhibiting an effect opposite to that on leaf N (Tables 23 to 26).

6.2.1. In the second experiment with barley also, values for the three growth characteristics studied were found to be significantly enhanced by the spray treatments, at both stages of growth (only at heading stage, fresh and dry weight being the exception). It is noteworthy that in general, "Dimecron-100" (D) alone as well as in combination with various doses of P proved to be superior in effect than the spray of P alone. The best results for tiller number and dry weight per plant were obtained by treatments P_3D (5.460 kg P_2O_5 plus 0.740 l D/ha), P_0D (0.740 l D / ha only) at the heading stage and 2 x P_1D (2 sprays each containing 1.365 kg P_2O_5 plus 0.740 l D / ha) at both heading and milky grain stages. Fresh weight was maximum in treatments P_3D, P_0D and P_2D (2.730 kg P_2O_5 plus 0.740 l D / ha) at heading stage (Table 29).

6.2.2. Out of the nine yield characteristics studied, six were affected significantly (only ear length, spikelet number and grain number per ear behaving differently).

6.2.3. Regarding ear number and ear weight, it may be noted that, generally the best results were obtained with sprays containing "Dimecron-100". For example 2 x P_1D, P_3D, P_0D, P_2D among these and 2 x P_1D_0 (1.365 kg P_2O_5 / ha without added D) gave equally high ear number whereas 2 x P_1D, P_3D and P_0D produced the heaviest ears (Table 30).

6.2.4. For the remaining yield characteristics, namely, 1000 grain weight, total yield of plants, total yeild of grains and total yield of straw, it was noted that the effect of treatment 2 x P_1D was significantly superior to that of all others, followed by the treatment P_3 D.

6.2.5. Unlike growth characteristics and ear number and ear weight per plant, "Dimecron-100" only (treatment P_0D) had little effect on test weight, and grain and straw yield. A similar observation was made about the treatments containing P alone.

6.2.6.1. The effect of different spray treatments on leaf NPK concentration was noted to be significant with the exception of that on K at milky grain stage. At heading stage, N was found to be enhanced generally by sprays containing D, whereas, at milky grain stage, sprays of various doses of P alone showed this effect, the addition of D generally showing comparatively depressing effect on leaf N (Table 31).

6.2.6.2. Leaf P was increased over the control, sprayed with water (P_0D_0) by all spray treatments containing P and/or D, the higher P doses proving more effective, at both stages of growth (Table 31).

6.2.6.3. Values for the effect of P sprays on leaf K at heading stage, at which the effect was significant, presented a picture totally different from that expected in cereals. The control (P_0D_0) and the treatment P_0D gave the highest values, whereas the higher doses of P depressed leaf K (Table 31).

6.3. The effect of sprays containing various combinations of P and D on growth and yield characteristics of Laha-101 was noted to be significant in Experiment 3 (Tables 32 to 34).

6.3.1. Generally, values for the three growth characteristics, namely, shoot length, fresh weight and dry weight, were enhanced by the higher doses of P at both stages of growth i.e. at flowering and fruiting stage. Unlike the results obtained for barley, in the case of mustard, application of D alone was not found to be beneficial although its effect was better than that of the lowest dose of P and of the control (P_0D_0) sprayed with water only (Table 32).

6.3.2. Yield characteristics, including per hectare yield of seed, oil and protein, gave higher values as a result of spray treatments as compared with the control (P_0D_0). The spray treatment 2 x P_1D was noted to be optimum for these characteristics.

Next in order was, P_3D, for seed and oil (but not for protein) yield. It was also observed that generally the spray of higher doses of P along with D was beneficial for obtaining higher seed and oil yield (Table 33).

6.3.3. The results obtained for the effect of various spray treatments on leaf NPK concentration at either of the two stages were noted to be significant (Table 34).

6.3.3.1. At flowering stage, leaf N concentration was enhanced generally by the higher P-containing doses, while the control, P_0D_0, gave the lowest value. At fruiting stage, most spray P doses had equal effect on leaf N. However, it is noteworthy that the highest dose (P_3) resulted in lowest leaf N value at this later stage (Table 34).

6.3.3.2. Leaf P concentration presented a more stable picture than leaf N. Whereas, P_3D_0, P_3D, 2 x P_1D_0 and 2 x P_1D, containing higher quantities of P, enhanced leaf P to the maximum at both stages of growth, the lower doses decreased it, with the control, P_0D_0, sprayed with water only, giving the lowest value (Table 34).

6.3.3.3. Leaf K was significantly affected by spray treatment only at the flowering stage. The control (P_0D_0) and "Dimecron-100" alone (D) gave the highest leaf K values. Most of the remaining treatments gave equal values so that a clear-cut picture of the effect of spray of P and D on leaf K could not emerge (Table 34).

6.3.4. The effect of various combinations of P and D in spray on the seed quality i.e. per cent oil and per cent protein in seed was found to be significant (Table 33). It may be noted by comparison with 6.3.2. above that the effect of the various treatments on oil percentage was generally parallel to, and that on protein percentage opposite to, their respective effect on total yield of seed (see also Table 33).

6.3.4.1. Like yield characteristics, the treatment 2 x P_1D was noted to be optimum for the percentage of oil in seed. It was followed by treatment P_3D. The effect of treatments P_1D, P_1D_0, which were low in P, and of P_0D_0 exhibited poorest response (Table 33).

6.3.4.2. Maximum percentage of protein in seed was noted in treatments P_0D, P_3D_0 and 2 x P_1D_0, only the first of which contained D. The treatments giving the poorest protein content were 2 x P_1D and P_3D. It is noteworthy that the general trend of the effect of treatments on protein percentage was almost the reverse of the results obtained for oil percentage in seed (Table 33).

6.4.1. In the fourth experiment also the affect of spray and soil treatments on the three growth characteristics of mustard was found to be significant at both stages of growth as was the interaction effect i.e. foliar x soil application (Tables 35 to 37).

6.4.1.1. At flowering stage, spray of sulphur (S) was found to stimulate the shoot length most. P spray produced the shortest plants at this stage but at fruiting stage the effect was totally reversed (Table 35).

6.4.1.2. The effect of spray P on fresh weight was found to be optimum at both stages, with spray S equalling it at fruiting stage (Table 35).

6.4.1.3. For dry weight, spray of phosphorus plus sulphur (PS) was noted to be best at flowering stage. At fruiting stage, however, this treatment was poorest in its effect on dry matter production (Table 35).

6.4.2. Regarding basal dressing, the treatment F_1 (20 kg P_2O_5 / ha) was best for shoot length and fresh weight at flowering stage, whereas, the value for the treatment F_2 (40 kg P_2O_5 / ha) was superior than that for F_1 at fruiting stage. For dry matter production, maximum value was obtained with the higher dose (F_2) at both stages of growth.

6.4.3. Regarding interaction, it may be admitted that no clear-cut picture emerged to designate any single combination as the optimum for all the three growth characteristics at both stages. It may, however, be concluded that F_1P was effective at the flowering stage and F_2S, at the fruiting stage, with the control F_0W (plants grown without basal P and sprayed with water) giving the poorest results at both stages (Table 35).

6.4.4. The effect of spray and soil treatments on yield characteristics, as well as that of the inter-action (spray x soil), was found to be significant (Table 36).

6.4.4.1. Per hectare seed and oil yield were highest as a result of spray of P as well as of PS, whereas P also gave highest protein yield.

6.4.4.2. Total yield of seed and oil calculated per hectare showed equally good effect of 20 and 40 kg basal P_2O_5 / ha (F_1 and F_2) as compared with F_0, whereas, the 20 kg dose (F_1) proved best for protein yield (Table 36).

6.4.4.3. The best combination for total seed and oil yield was noted to be F_1P and for protein yield F_2PS, whereas F_0W proved the poorest combination for all three yield characteristics studied (Table 36).

6.4.5. The effect of spray treatments on leaf NPK was mostly significant, the exception being K at fruiting stage. The same could not be said for the effect of basal P and of the interaction, spray x basal P (Table 37). It may be pointed out that spray P and PS generally enhanced leaf N and leaf P concentration at flowering stage, whereas spray P proved best at the fruiting stage. For leaf K values, spray S gave the best results at flowering stage.

6.4.6. The two parameters selected for seed quality were mostly affected significantly (Table 36). Like the data for Experiment 3, treatments favouring the percentage of oil were found to be detrimental for seed protein percentage.

6.4.6.1. For oil percentage, the best treatment was spray of sulphur alone containing 2 kg S / ha (S), that of water giving the lowest value. Basal dressing with 20 kg P_2O_5 / ha gave the best results among soil treatments. Here also the control (no basal P) proved the poorest. It may be pointed out that F_1S proved the best combination to obtain the highest oil percentage, with F_0W giving the poorest results (Table 36).

6.4.6.2. The value for the percentage of protein was lowest in the treatments containing sulphur in the spray, the other treatments, including the control (W) proving much superior. The effect of basal dressing on this seed quality was non-significant. The combination F_2PS proved to be the best for percentage of seed protein, with F_0PS and F_2S giving the lowest values.

6.5.1. The findings of the present investigation summarised above and the conclusions drawn therefrom have been discussed critically in the light of the publications of other workers (Chapter V).

6.5.2. In the end, future lines of work have also been indicated with an eye on national needs, particularly from the point of view of increased production and fertiliser economy (Chapter V).

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